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THRUST COEFFICIENTS, THRUST DEFLECTION ANGLES, AND NONDIMENSIONAL MOMENTS FOR NOZZLES WITH OBLIQUE EXIT PLANES

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13. ABSTRACT

Nozzles with oblique exit planes, scarfed nozzles, are encountered in aerospace applications such as reaction control and thrust reversal systems. This document provides thrust coefficient, thrust deflection angle, and nondimensional turning moment data for scarfed conical nozzles on machine-generated graphs. Based on one-dimensional isentropic flow of a perfect gas, the data cover specific heat ratios from 1.18 to 1.40, nozzle half-angles from 5 to 25 degrees, scarf angles from 10 to 60 degrees, area ratios at the upstream scarf point from 1.5 to 15, and ratios of chamber pressure to ambient pressure from 20 to infinity (vacuum).

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Nozzles, thrust coefficients						
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U3 4802 1030 REV 7/66

PART 2 OF 3

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THRUST COEFFICIENTS, THRUST DEFLECTION ANGLES, AND NONDIMENSIONAL MOMENTS FOR NOZZLES WITH OBLIQUE EXIT PLANES

March 1968

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Missile and Information Systems Division
Aerospace Group
THE BOEING COMPANY
Seattle, Washington

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LIST OF GRAPHS

Graphs of thrust coefficient, deflection angle, and nondimensional moment are listed below.

PREFACE

Nozzles with oblique exit planes, scarfed nozzles, are encountered in aerospace applications such as reaction control and thrust reversal systems. This document provides thrust coefficient, thrust deflection angle, and nondimensional turning moment data for scarfed conical nozzles on machine-generated graphs. Based on one-dimensional isentropic flow of a perfect gas, the data cover specific heat ratios from 1.18 to 1.40, nozzle half-angles from 5 to 25 degrees, scarf angles from 10 to 60 degrees, area ratios at the upstream scarf point from 1.5 to 15, and ratios of chamber pressure to ambient pressure from 20 to infinity (vacuum).

The data presented herein were developed by the Rocket Propulsion Research Staff of the Missile and Information Systems Division of The Boeing Company. An original analysis by Robert Hopcroft was extended in scope and programmed for computation by Ross Fiedler and William Phillips. Mike Whitaker programmed the machine plotting. William Phillips wrote the text and coordinated printing.

SYMBOLS

(See Figures A and B on Page vii)

A_t	Nozzle throat area
$C_{F_{sc}}$	Total thrust coefficient
C_{F_o}	Thrust coefficient for symmetrical section of nozzle (corrected for flow divergence)
C_{T_x}	Total thrust coefficient in x-direction
C_{T_y}	Total thrust coefficient in y-direction
F_x	Thrust produced by scarfed section of nozzle in x-direction
F_y	Thrust produced by scarfed section of nozzle in y-direction
L	Length of scarfed section of nozzle
$M_{zo_{ND}}$	Nondimensional moment produced about z-axis at point o (positive in clockwise direction)
P	Pressure at any point inside scarfed section
P_a	Ambient pressure
P_c	Chamber pressure
R	Radius of nozzle at any point inside scarfed section
R_o	Radius of nozzle at upstream scarf point
R_t	Nozzle throat radius
T	Total thrust produced by the nozzle
T_x	Total thrust in x-direction
T_y	Total thrust in y-direction
x	Axial distance inside nozzle from point o
y	Distance inside nozzle perpendicular to axis
α	Nozzle half-angle
β	Direction of radius vector R
γ	Specific heat ratio
θ	Thrust deflection angle
ϕ	Nozzle scarf angle

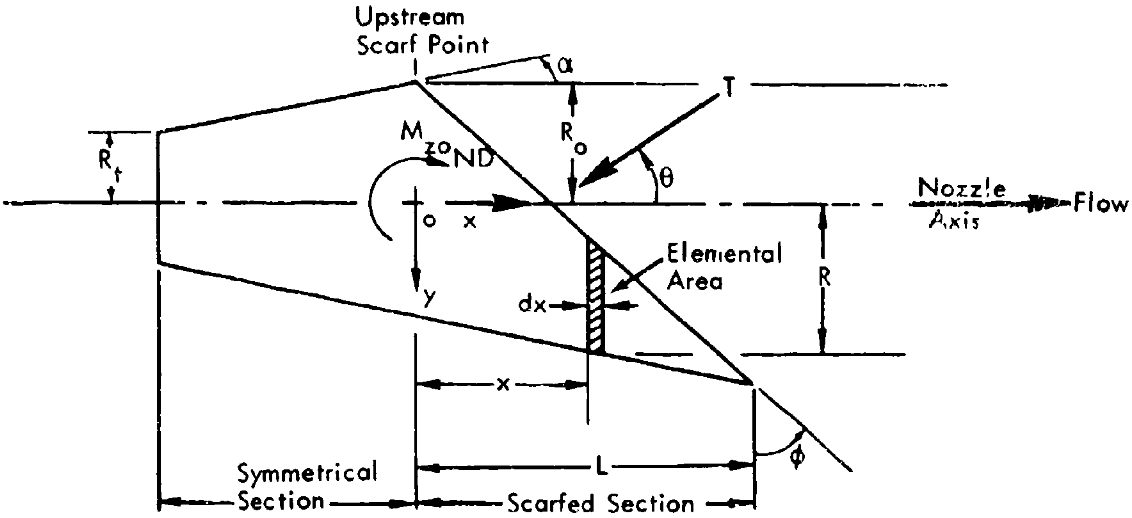

Figure A: SIDE VIEW OF SCARFED CONICAL NOZZLE

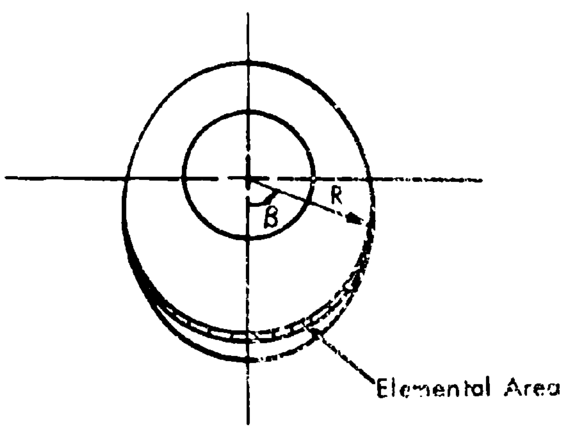

Figure B: END VIEW OF SCARFED CONICAL NOZZLE

ANALYSIS

ASSUMPTIONS AND LIMITATIONS

1) The flow is accelerated from stagnation conditions.

2) The gases obey the perfect gas laws.

3) The flow is one-dimensional, steady, and isentropic.

4) The momentum term of the thrust equation is corrected for divergence of the gas flow.

5) The data provided exclude those cases where:

   a) Expansion fans originating from the upstream scarf point would intersect the opposite wall of the nozzle;

   b) Flow separation would occur inside the nozzle.

EQUATIONS

The scarfed nozzle thrust coefficient, deflection angle, and nondimensional moment are defined as follows:

$$C_{F_{sc}} = \frac{T}{P_c A_t}$$

$$\theta = \tan^{-1}\left(\frac{T_y}{T_x}\right)$$

$$M_{zo_{ND}} = \frac{\int_o^L x \, dF_y + \int_o^L y \, dF_x}{P_c R_t^3}$$

The thrust coefficient and deflection angle are calculated from:

$$C_{F_{sc}} = \sqrt{C_{T_x}^2 + C_{T_y}^2}$$

$$\theta = \tan^{-1}\left(\frac{C_{T_y}}{C_{T_x}}\right)$$

where,

$$C_{T_x} = \frac{2 \tan \alpha}{\pi} \int_o^{L/R_t} \left(\frac{P}{P_c} - \frac{P_a}{P_c}\right) \frac{R}{R_t} \ \beta \ d\left(\frac{x}{R_t}\right) + C_{F_o}$$

$$C_{T_y} = \frac{2}{\pi} \int_o^{L/R_t} \left(\frac{P}{P_c} - \frac{P_a}{P_c}\right) \frac{R}{R_t} \sin \beta \ d\left(\frac{x}{R_t}\right)$$

The nondimensional moment is calculated from:

$$M_{zo_{ND}} = 2 \tan \alpha \int_o^{L/R_t} \left(\frac{P}{P_c} - \frac{P_a}{P_c}\right)\left(\frac{R}{R_t}\right)^2 \sin \beta \ d\left(\frac{x}{R_t}\right)$$

$$+ 2 \int_o^{L/R_t} \left(\frac{P}{P_c} - \frac{P_a}{P_c}\right)\left(\frac{R}{R_t}\right) \sin \beta \frac{x}{R_t} \ d\left(\frac{x}{R_t}\right)$$

The moment axis is perpendicular to the nozzle plane of symmetry at a point on the nozzle axis opposite the upstream scarf point (point o in the diagram on Page vii). The pressure ratio, P/P_c, is determined from one-dimensional isentropic flow theory. The parameters R/R_t, L/R_t, and β are expressed in terms of the nozzle half-angle, scarf angle, and initial area ratio.

COMPUTATIONAL ACCURACY

The implicit relationship between pressure ratio and area ratio requires that an iterative computation be carried out to determine the pressure ratio at the upstream scarf point and the pressure profile in the scarfed section of the nozzle, which is required for numerical integration of the forces. The number of increments in the integration procedure has been selected to ensure an accuracy of 0.006% in the calculations.

EXPLANATION OF GRAPHS

USE OF GRAPHS

The plots of the performance parameters as functions of the ratio of chamber pressure to ambient pressure are discontinued at the maximum *calculated* value of initial expansion ratio (less than 15.0) for which separation does not occur downstream in the scarfed section. The performance parameters were calculated for each half-unit of expansion ratio from 1.5 to 15. Separation criteria from the accumulation of data presented* are employed to provide limits to the calculated data for initial expansion ratios of less than 15.

With initial expansion ratios equal to or greater than 1.5, the minimum for which data are calculated, expansion waves originating from the upstream scarf point will not intersect the opposite wall (thus influencing the pressure distribution on the nozzle wall), provided the scarf angle is not greater than 60 degrees for nozzle half-angles of 5 degrees or more. Any extrapolation of the curves below a scarf-point area ratio of 1.5 must be checked for this condition.

Linear interpolation may be used to obtain values of the performance parameters for low intermediate values of scarf angle and nozzle half-angle without incurring errors greater than 1%. For values of scarf angle greater than 40 degrees and nozzle half-angle greater than 20 degrees, errors of up to 10% may be incurred.

PLOTTING ACCURACY

These graphs were machine-plotted with an accuracy of 0.5% compared to the computed data.

SEQUENCE OF GRAPHS

The graphs are divided into four sections, one for each value of specific heat ratio of 1.18, 1.20, 1.22, and 1.40. For each specific heat ratio there are five values of nozzle half-angle: 5, 10, 15, 20, and 25 degrees. For each nozzle half-angle there are 27 graphs, of which the first three are carpet plots of each of the performance parameters as functions of initial area ratio and scarf angle for vacuum conditions. On the following 24 pages, the graphs of thrust coefficient, deflection angle, and moment as functions of initial area ratio and ambient pressure are arranged together for each value of scarf angle: 10, 20, 30, 40, 45, 50, 55, and 60 degrees.

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* Arens, M., and E. Spiegler, "Shock-Induced Boundary Layer Separation in Overexpanded Conical Exhaust Nozzles," *AIAA Journal*, March 1963.

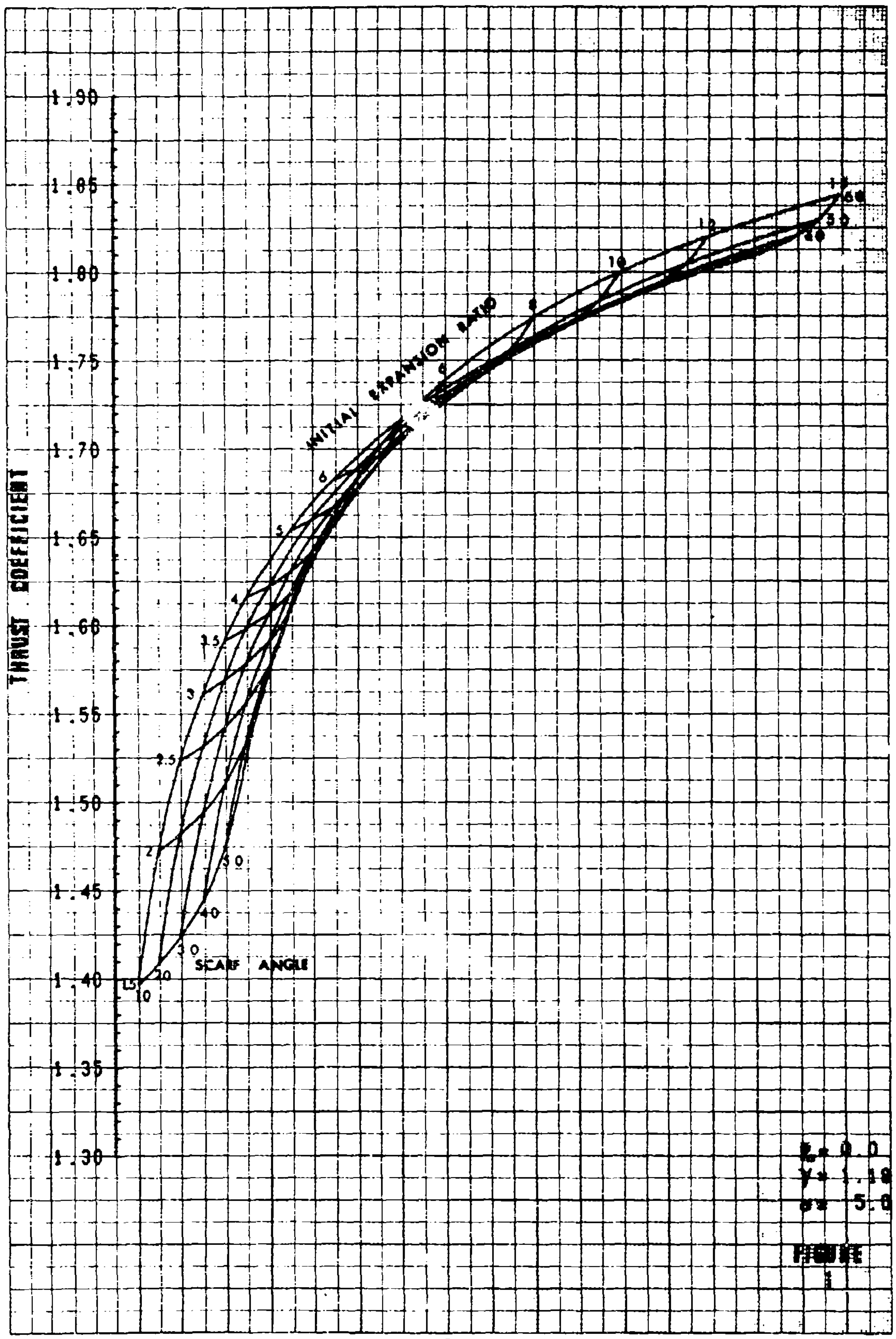

THRUST COEFFICIENT
INITIAL EXPANSION RATIO
SCARF ANGLE
1.90
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
γ = 1.18
5.0

FIGURE 1

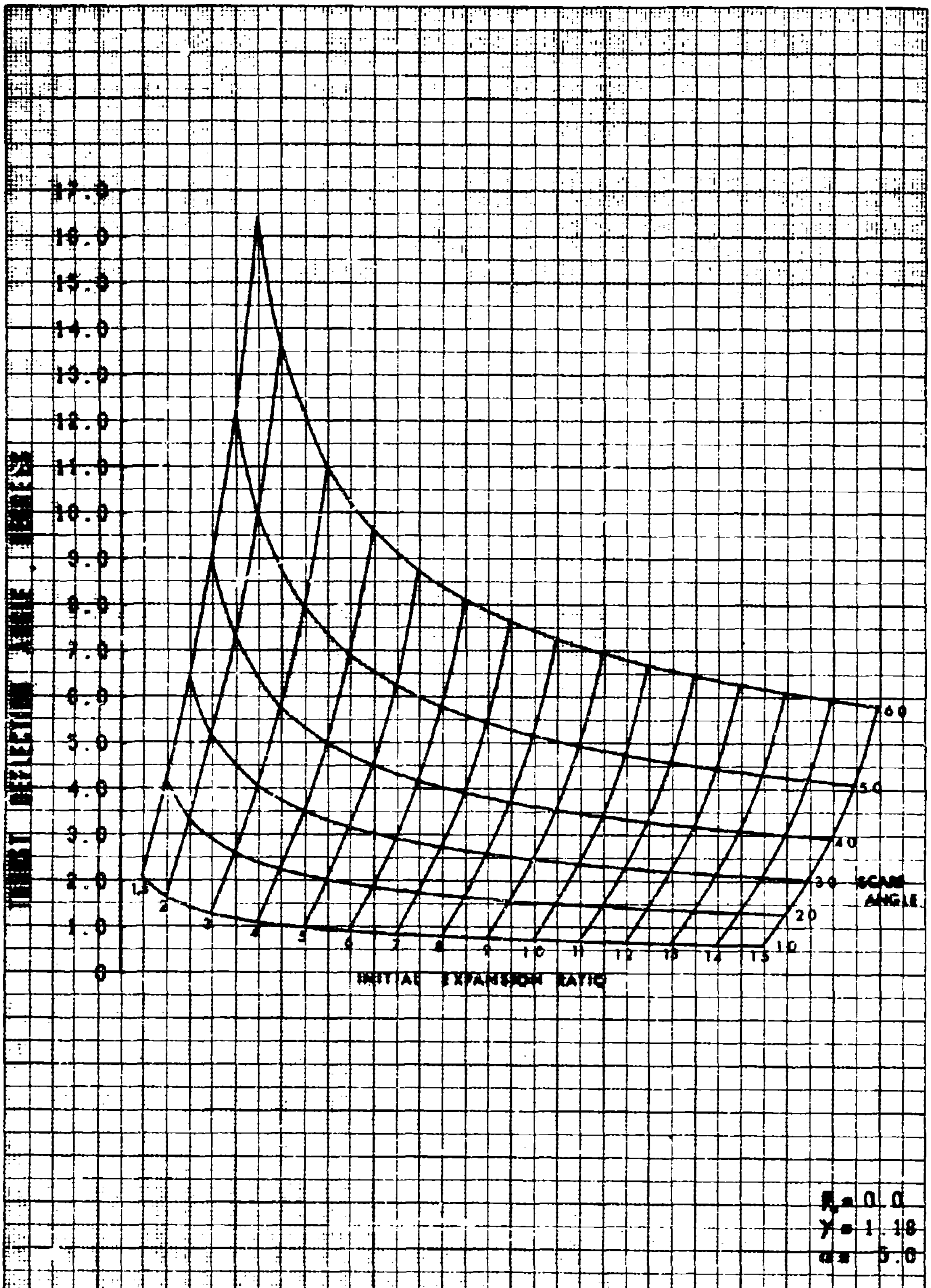
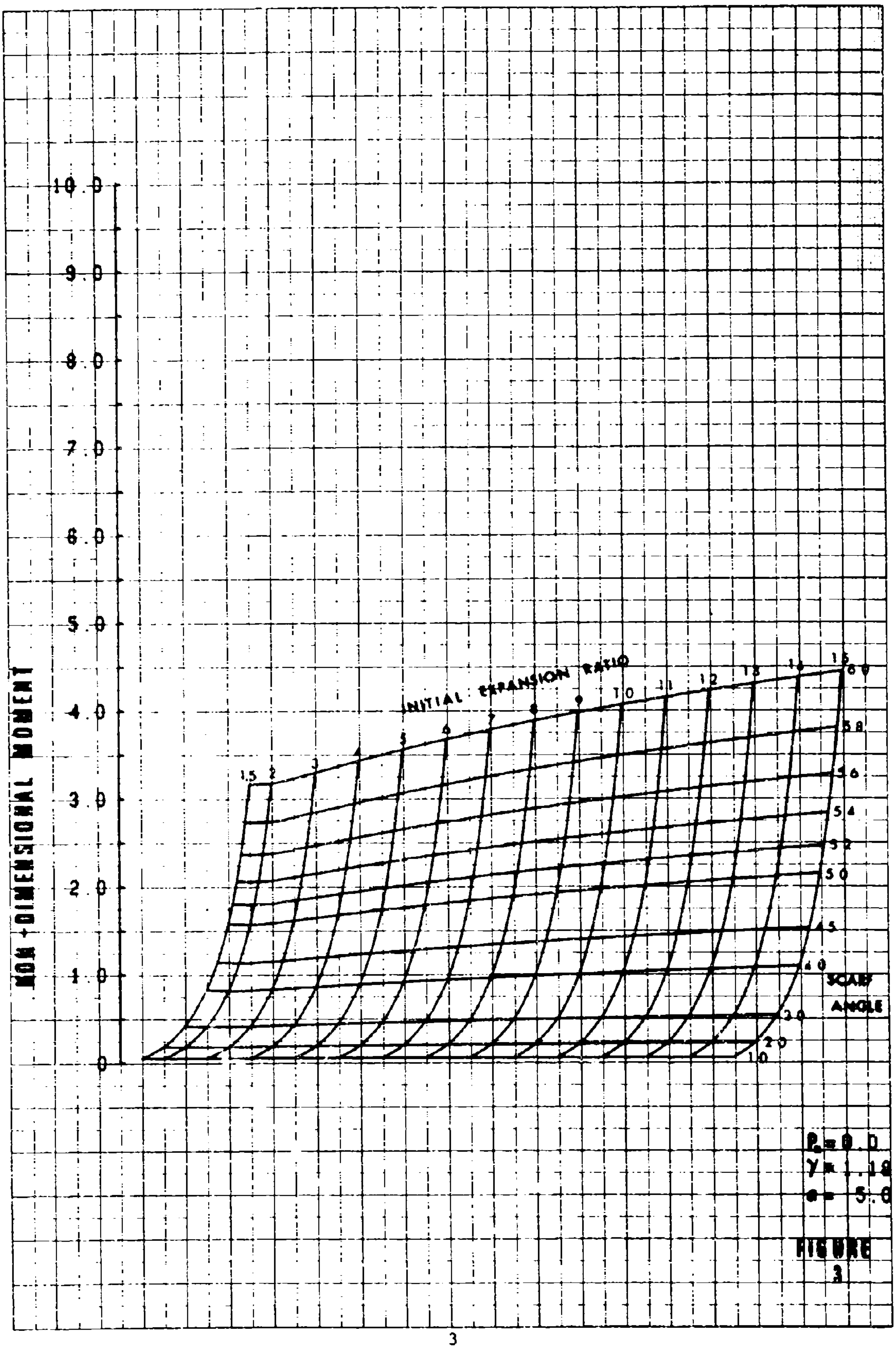
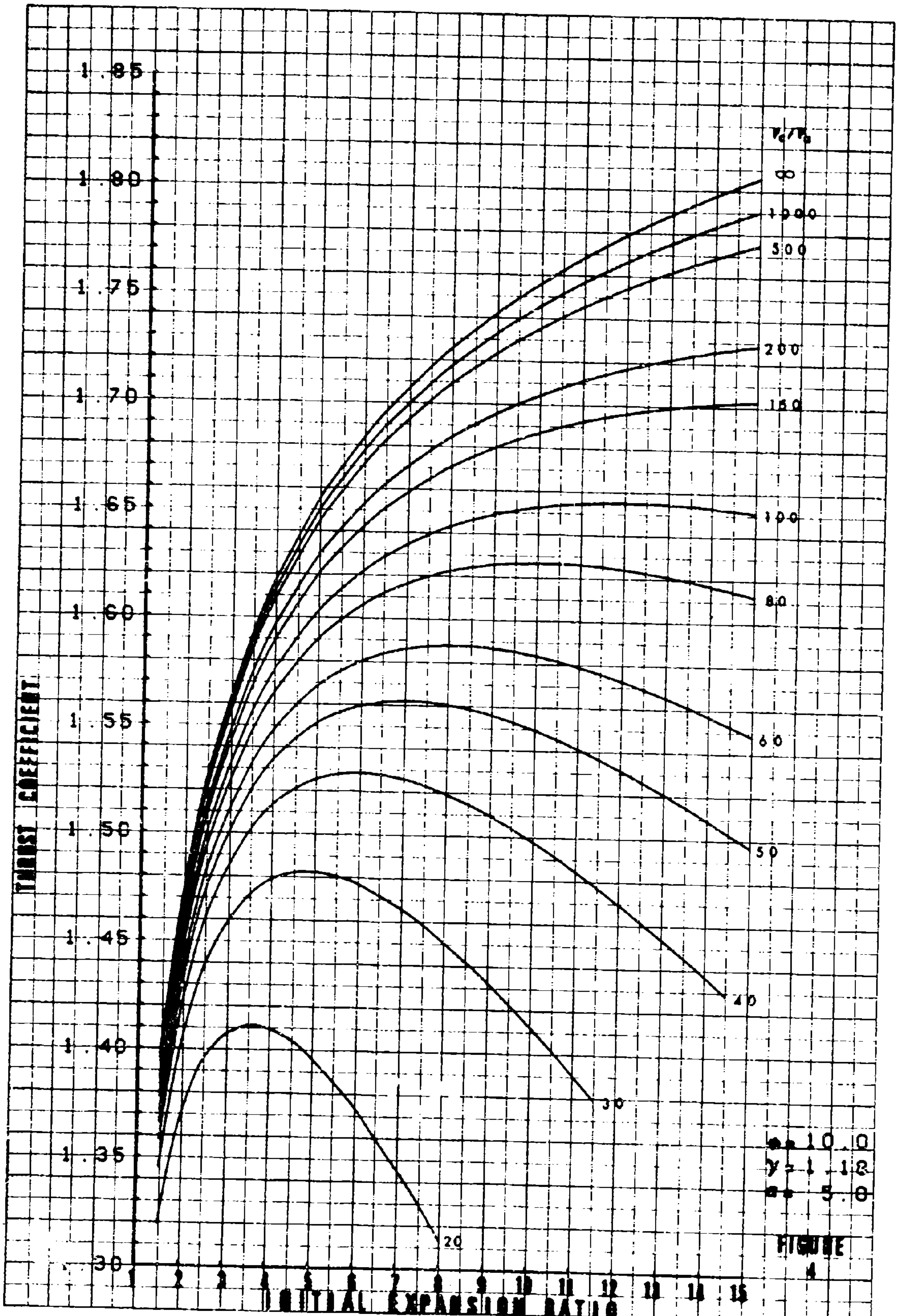
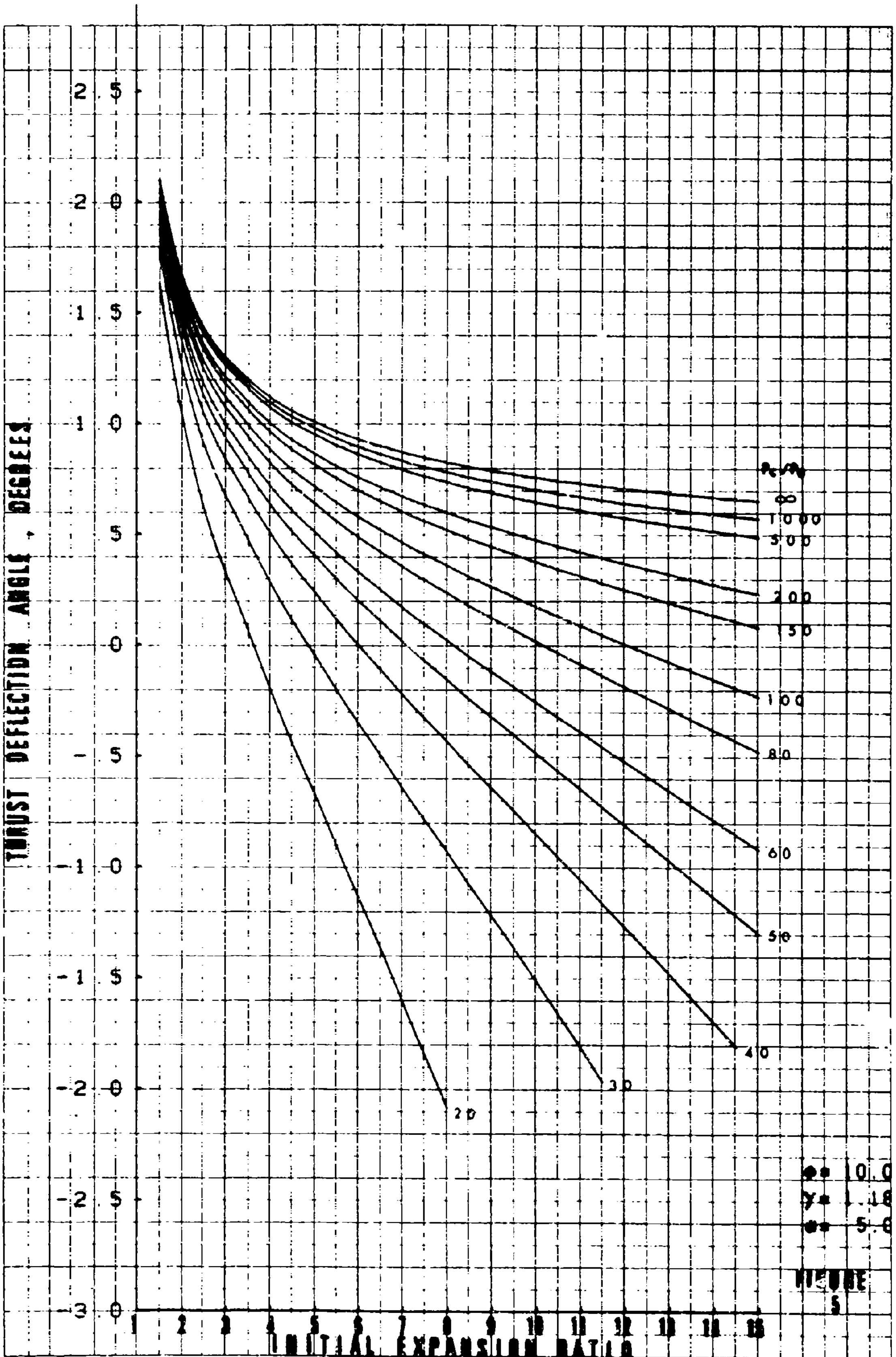
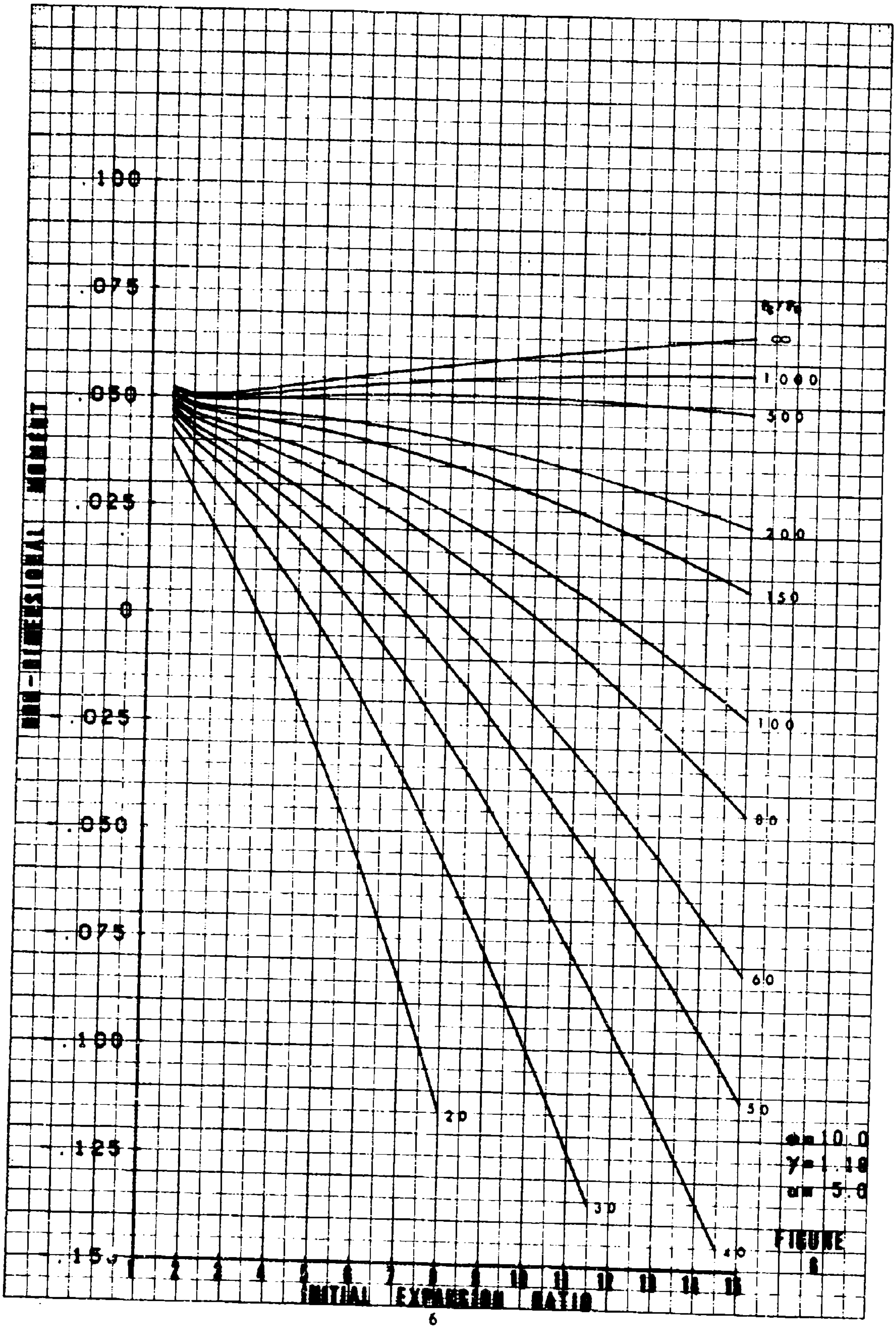

17.0
16.0
15.0
14.0
13.0
12.0
11.0
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
1.5
2
3
4
5
6
7
8
9
10
11
12
13
14
15
INITIAL EXPANSION RATIO
10
20
30
40
50
60
SCARF ANGLE
P_a = 0.0
γ = 1.18
α = 5.0

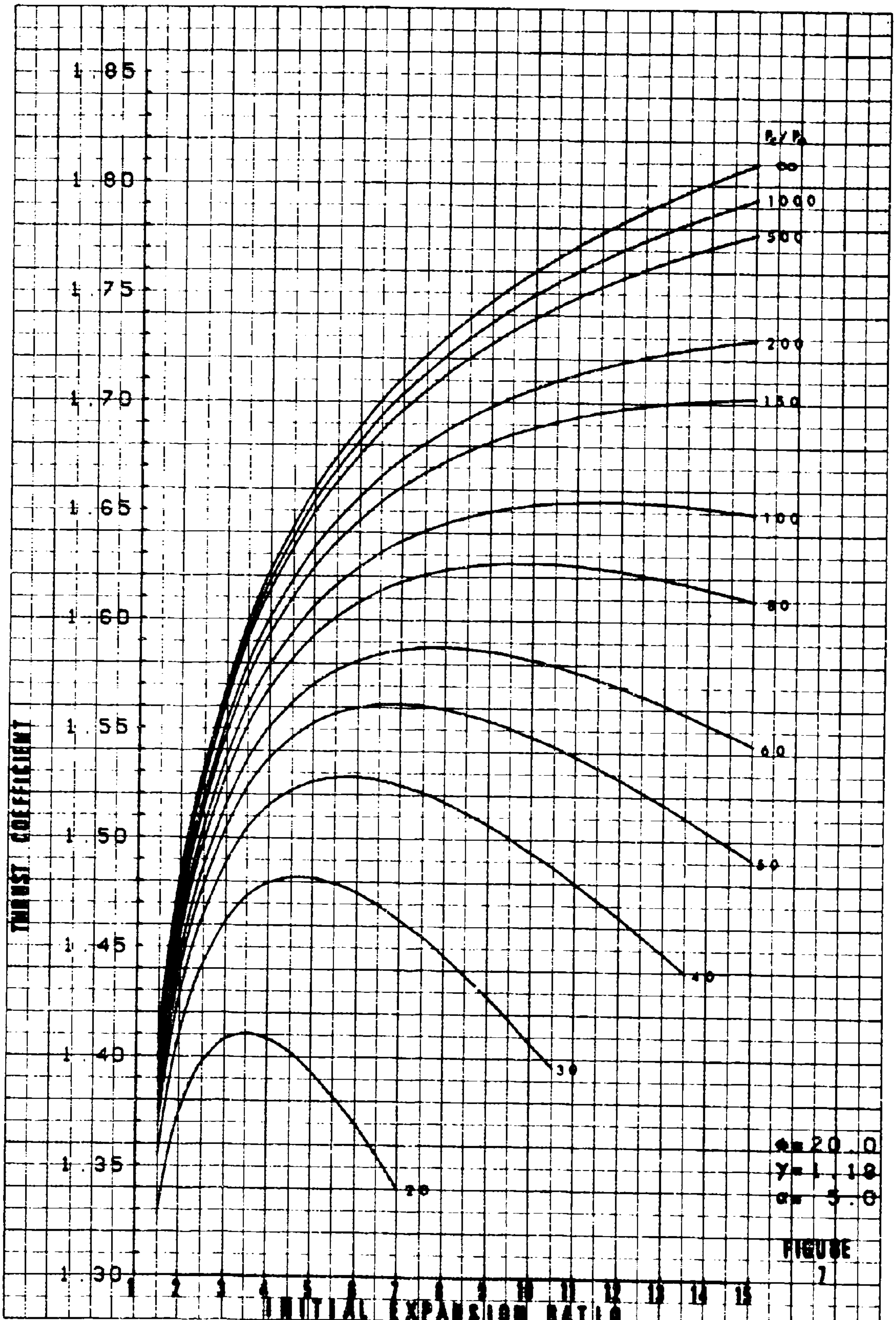
FIGURE 2


NON-DIMENSIONAL MOMENT
INITIAL EXPANSION RATIO
SCARF ANGLE
P_a = 0.0
γ = 1.18
θ = 5.0
FIGURE 3


THRUST COEFFICIENT
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
P_c/P_a
∞
1000
500
200
150
100
80
60
50
40
30
20
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
γ = 1.18
FIGURE 4


THRUST DEFLECTION ANGLE, DEGREES
2.5
2.0
1.5
1.0
.5
0
-.5
-1.0
-1.5
-2.0
-2.5
-3.0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
INITIAL EXPANSION RATIO
P_c/P_a
∞
1000
500
200
150
100
80
60
50
40
30
20
FIGURE
5


NON-DIMENSIONAL MOMENT
.100
.075
.050
.025
0
-.025
-.050
-.075
-.100
-.125
-.150
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
∞
1000
500
200
150
100
80
60
50
40
30
20
10.0
FIGURE


THRUST COEFFICIENT
INITIAL EXPANSION RATIO
P_c/P_a
∞
1000
500
200
150
100
80
60
50
40
30
20
φ = 20.0
γ = 1.18
α = 5.0
FIGURE 7

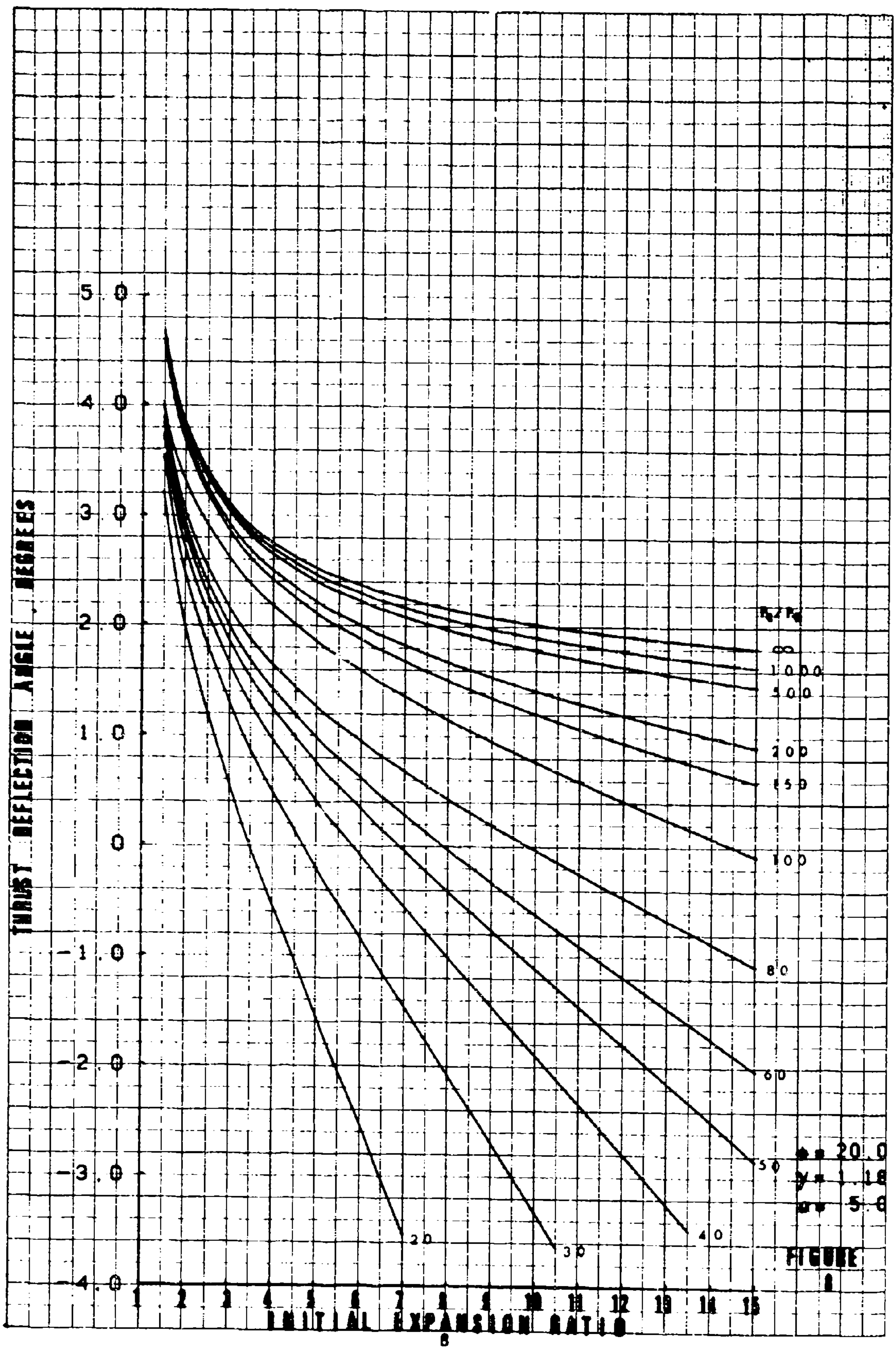
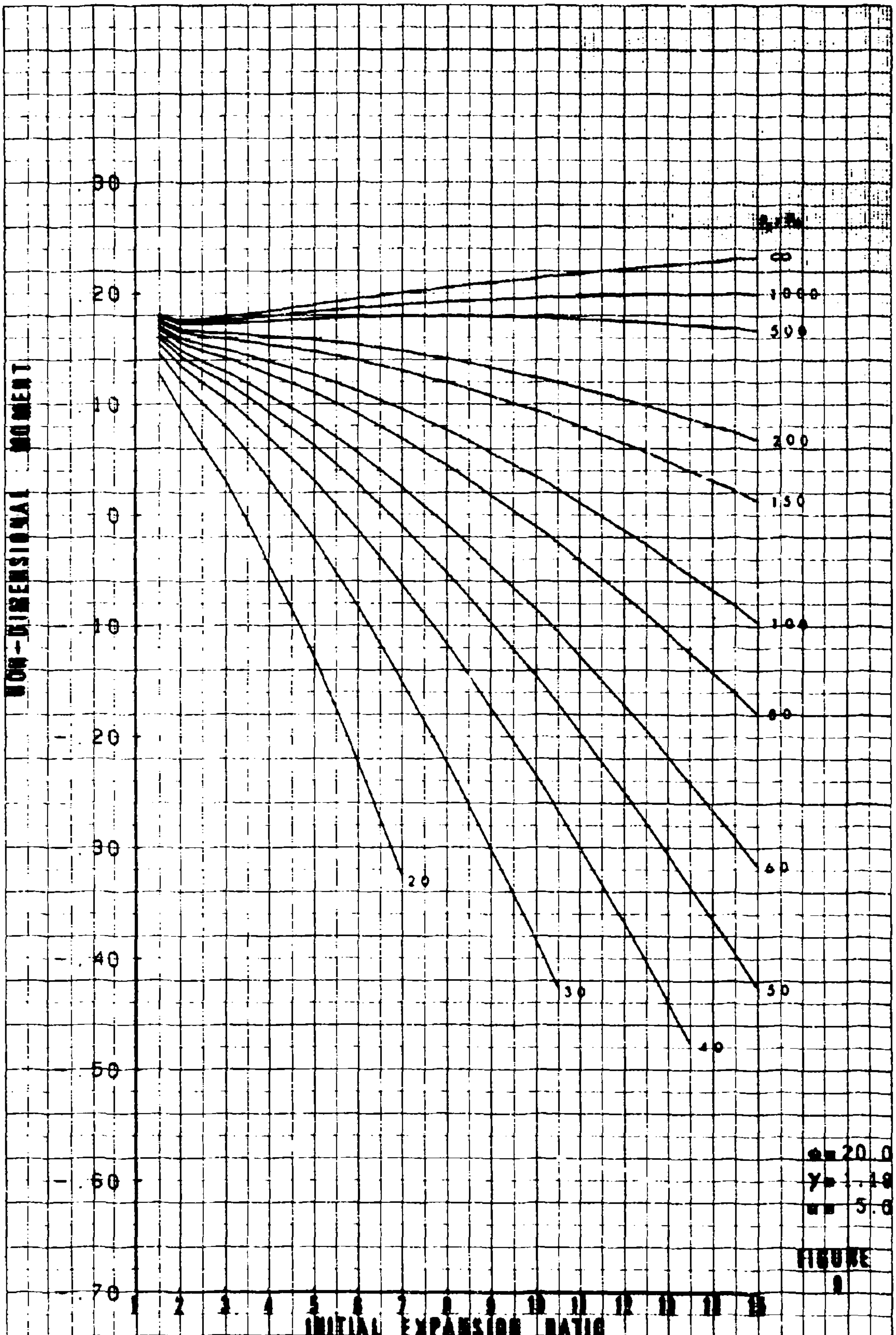
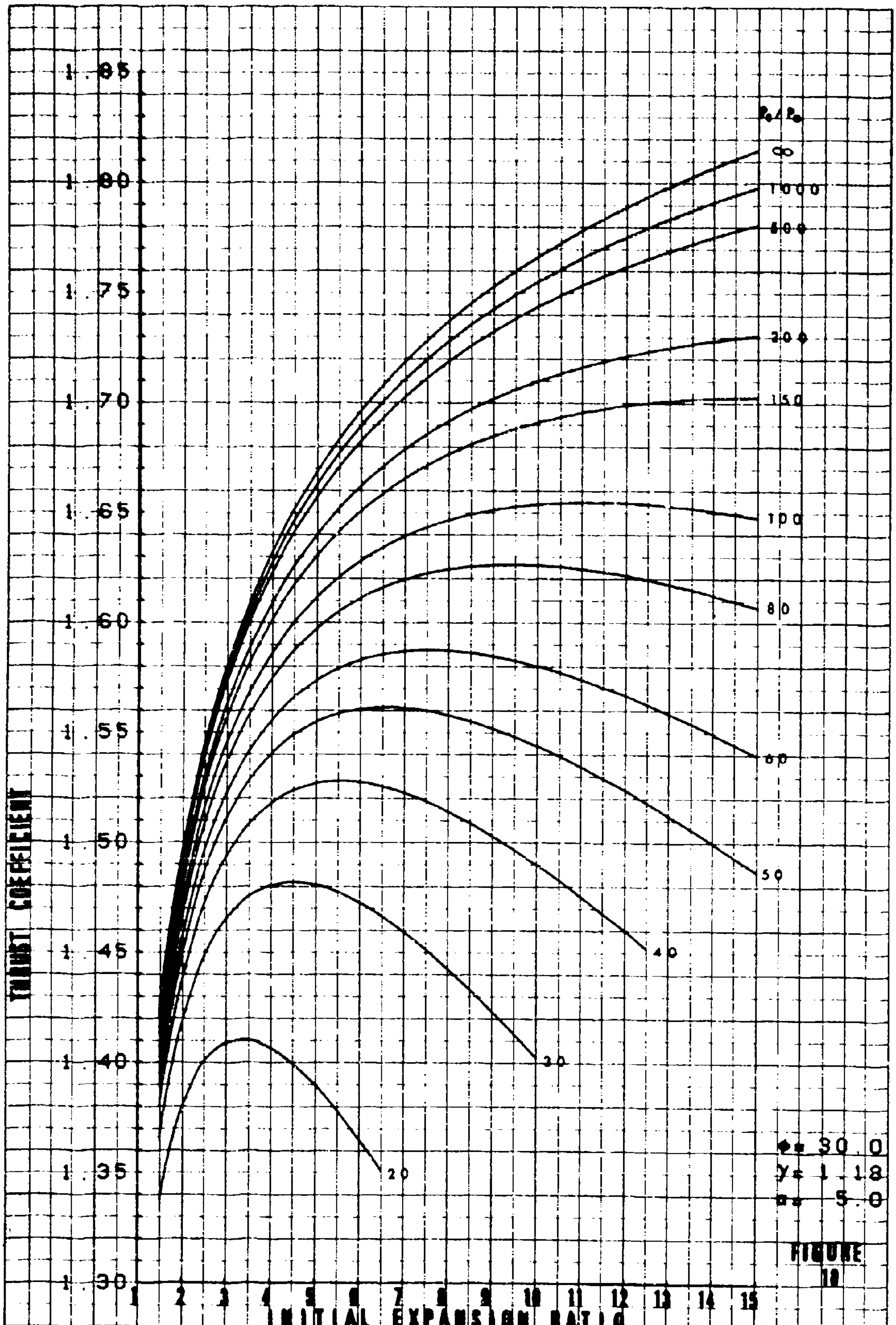

5.0
4.0
3.0
2.0
1.0
0
-1.0
-2.0
-3.0
-4.0
THRUST DEFLECTION ANGLE, DEGREES
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
ε
∞
1000
500
200
150
100
80
60
50
40
30
20

FIGURE
8


NON-DIMENSIONAL MOMENT
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
INITIAL EXPANSION RATIO
∞
1000
500
200
150
100
80
60
50
40
30
20
FIGURE



1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
THRUST COEFFICIENT
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
P_o/P_a
∞
1000
500
200
150
100
80
60
50
40
30
20
ϕ = 30.0
γ = 1.18
α = 5.0
FIGURE

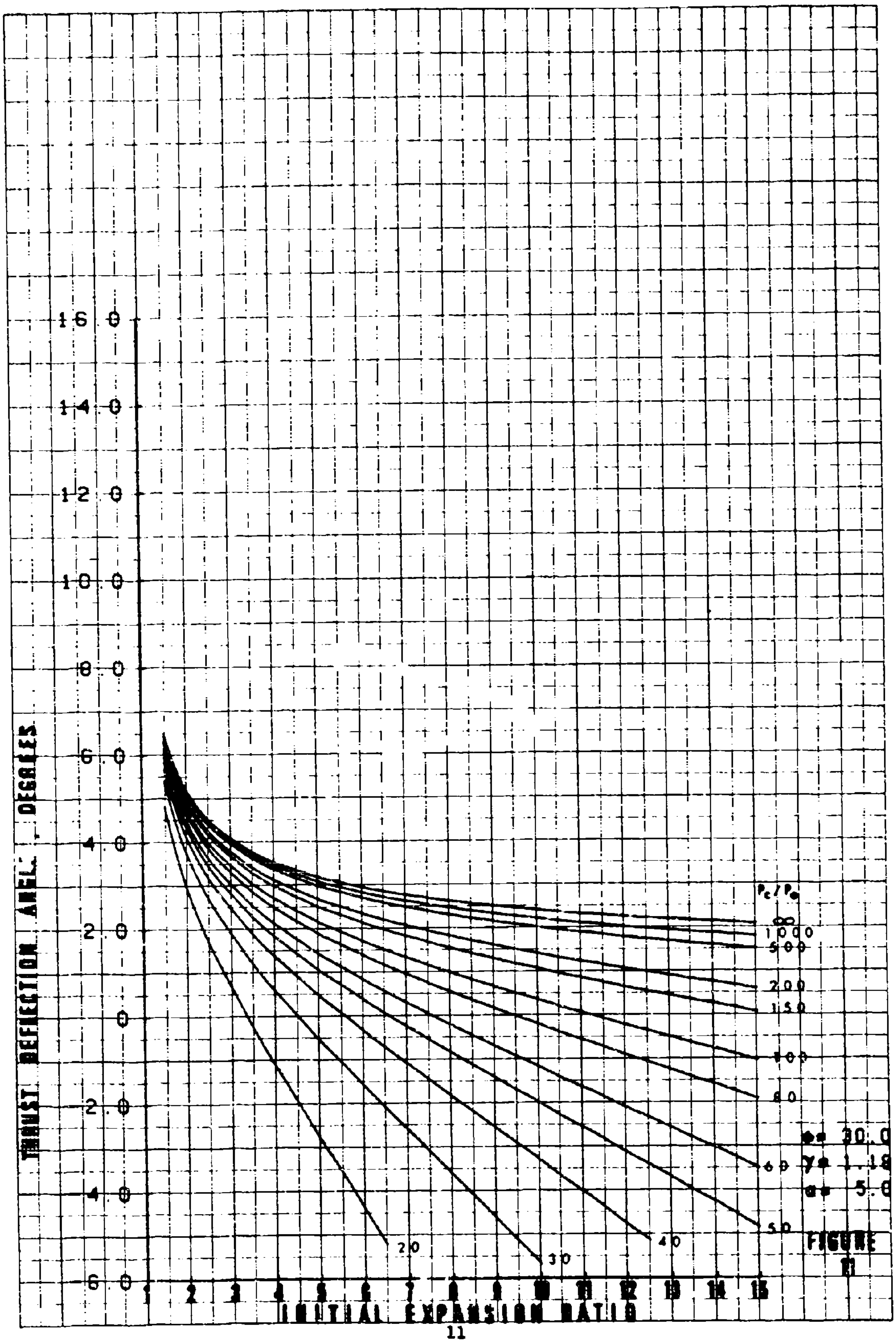
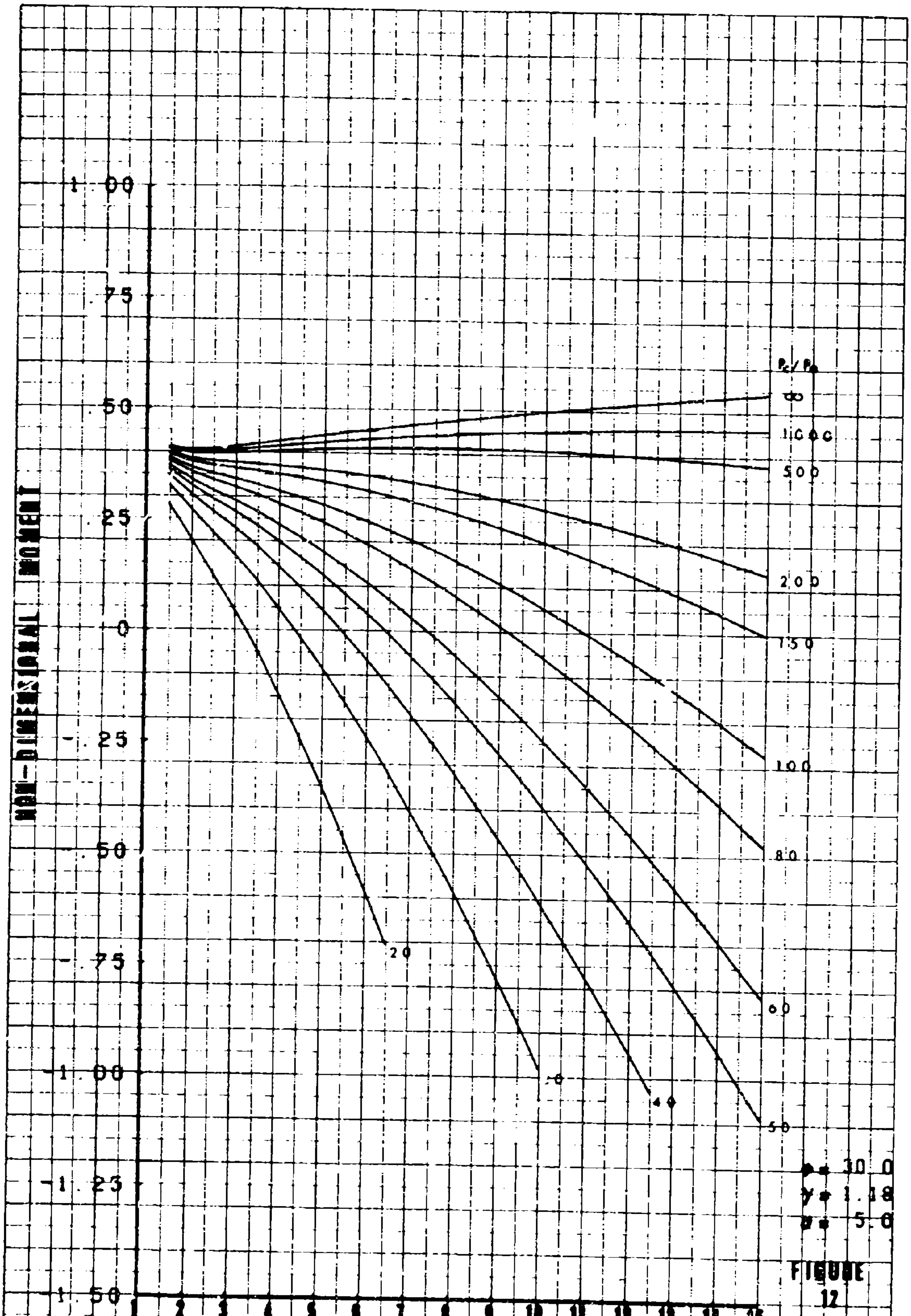
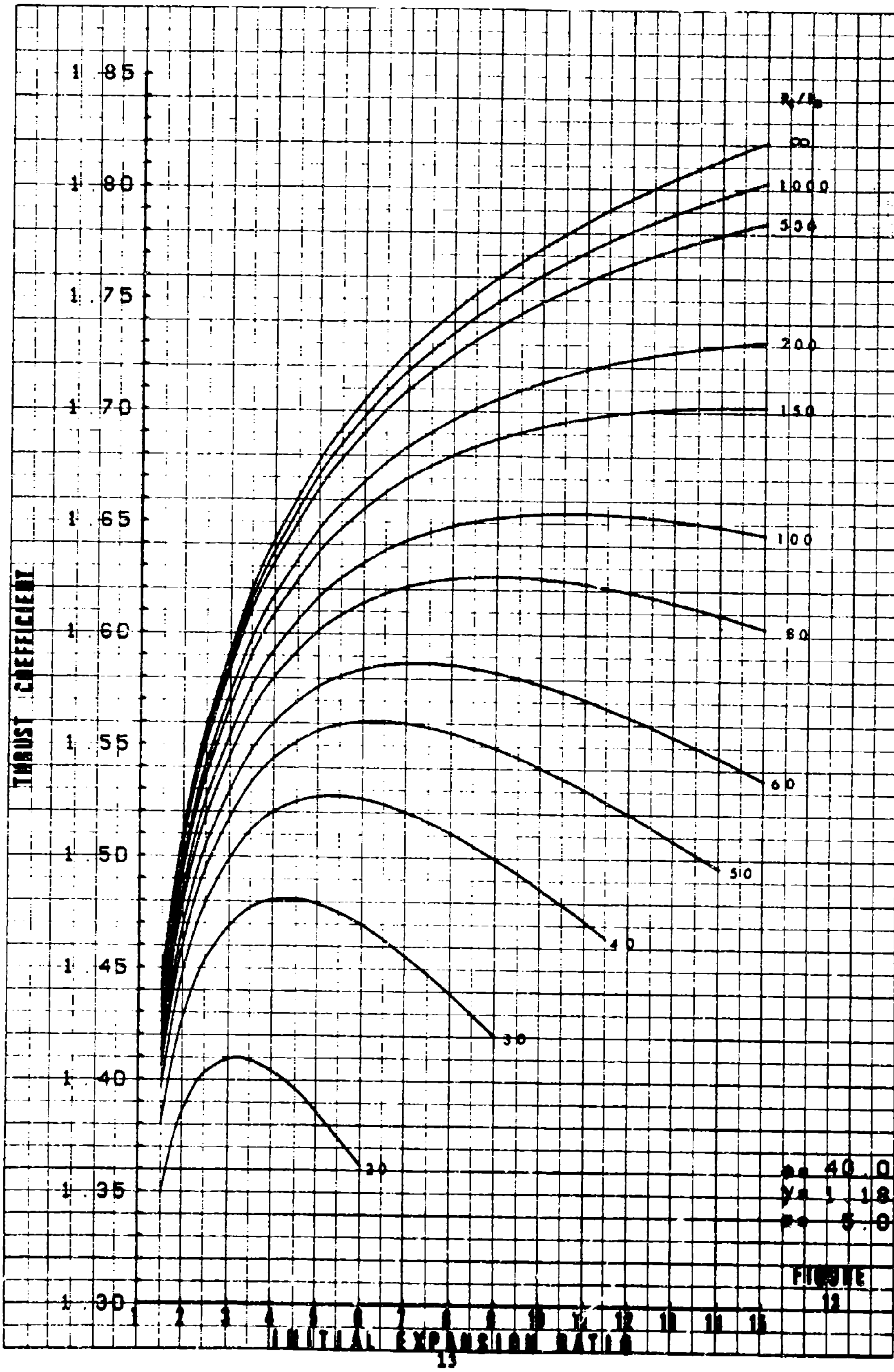

THRUST DEFLECTION ANGLE, DEGREES
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0
-2.0
-4.0
-6.0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
INITIAL EXPANSION RATIO
P_c/P_a
∞
1000
500
200
150
100
80
60
50
40
30
20

FIGURE 11


NON-DIMENSIONAL MOMENT
INITIAL EXPANSION RATIO
1.00
.75
.50
.25
0
-.25
-.50
-.75
-1.00
-1.25
-1.50
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
P_c/P_a
∞
1000
500
200
150
100
80
60
50
40
30
20
θ = 30.0
γ = 1.18
α = 5.0
FIGURE 12


1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
THRUST COEFFICIENT
INITIAL EXPANSION RATIO
1000
500
200
150
100
80
60
40
30
20
FIGURE
12

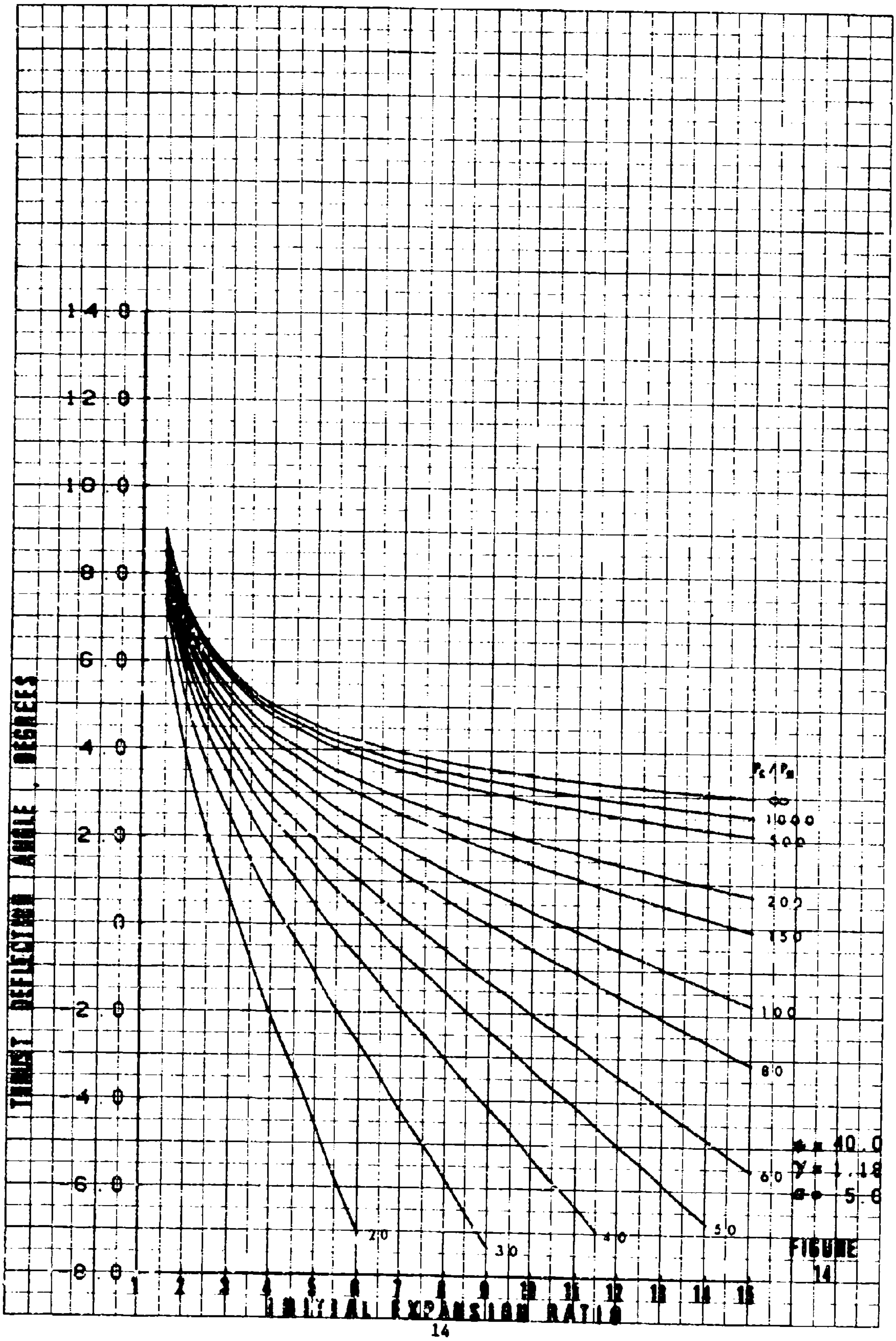
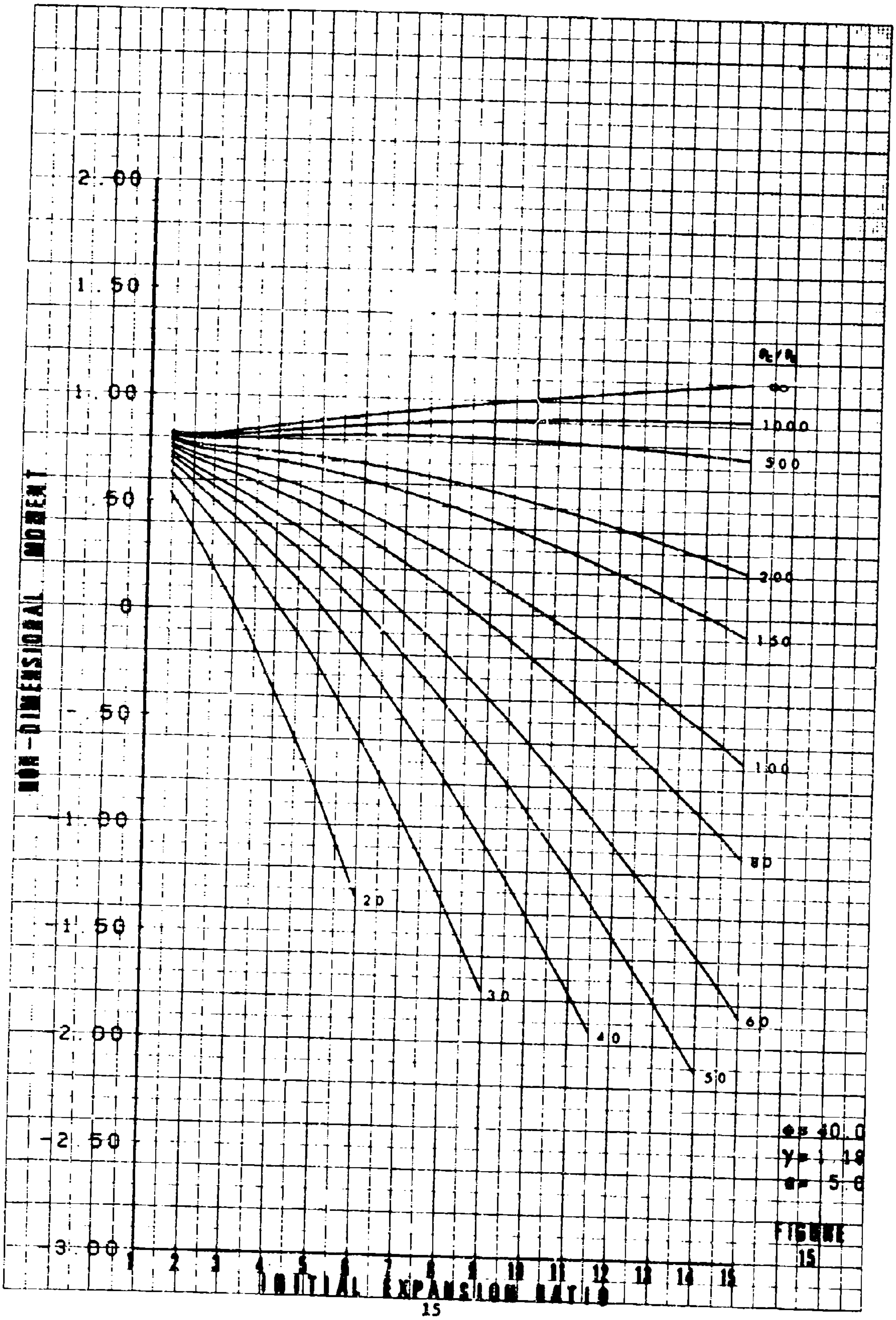
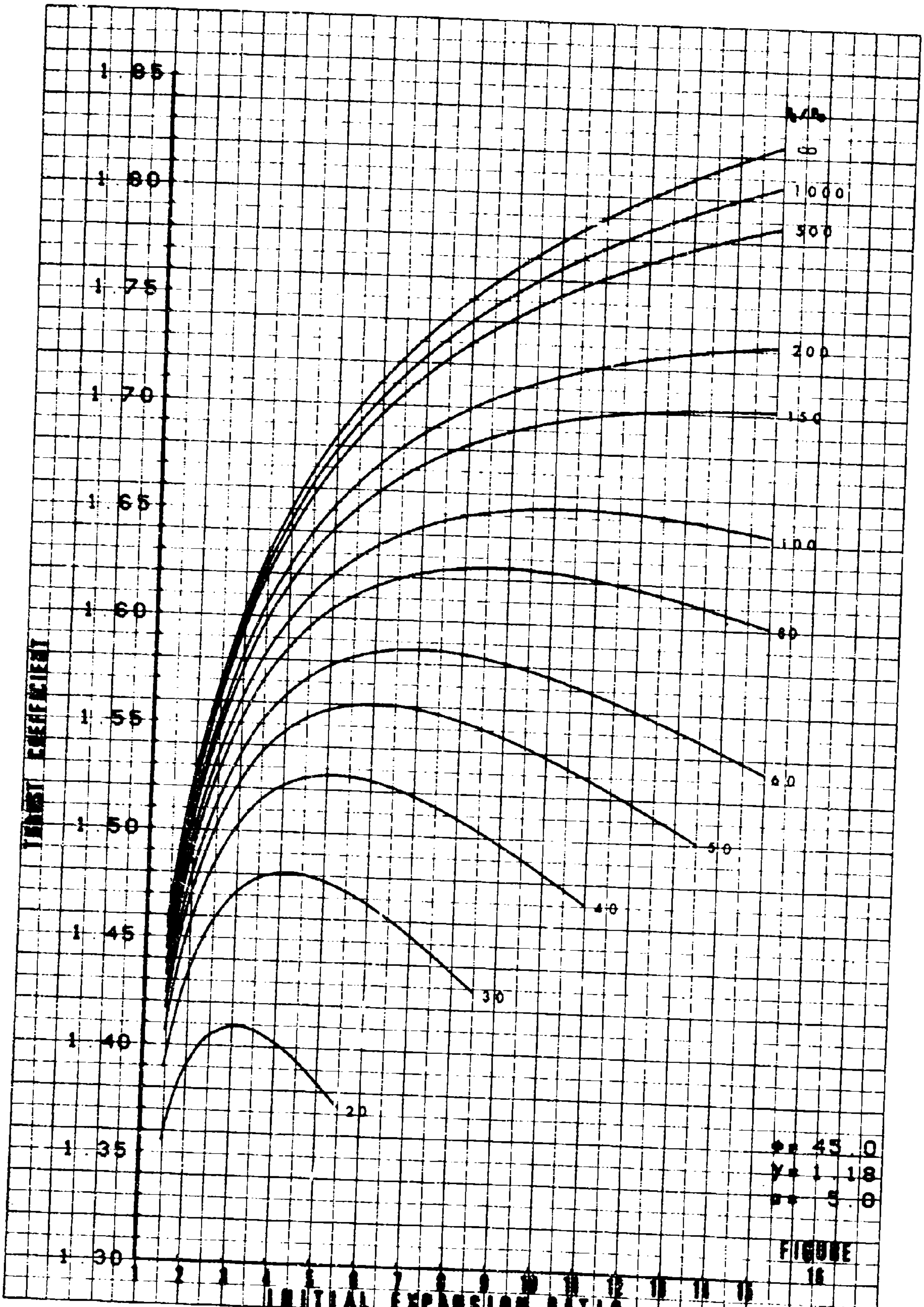
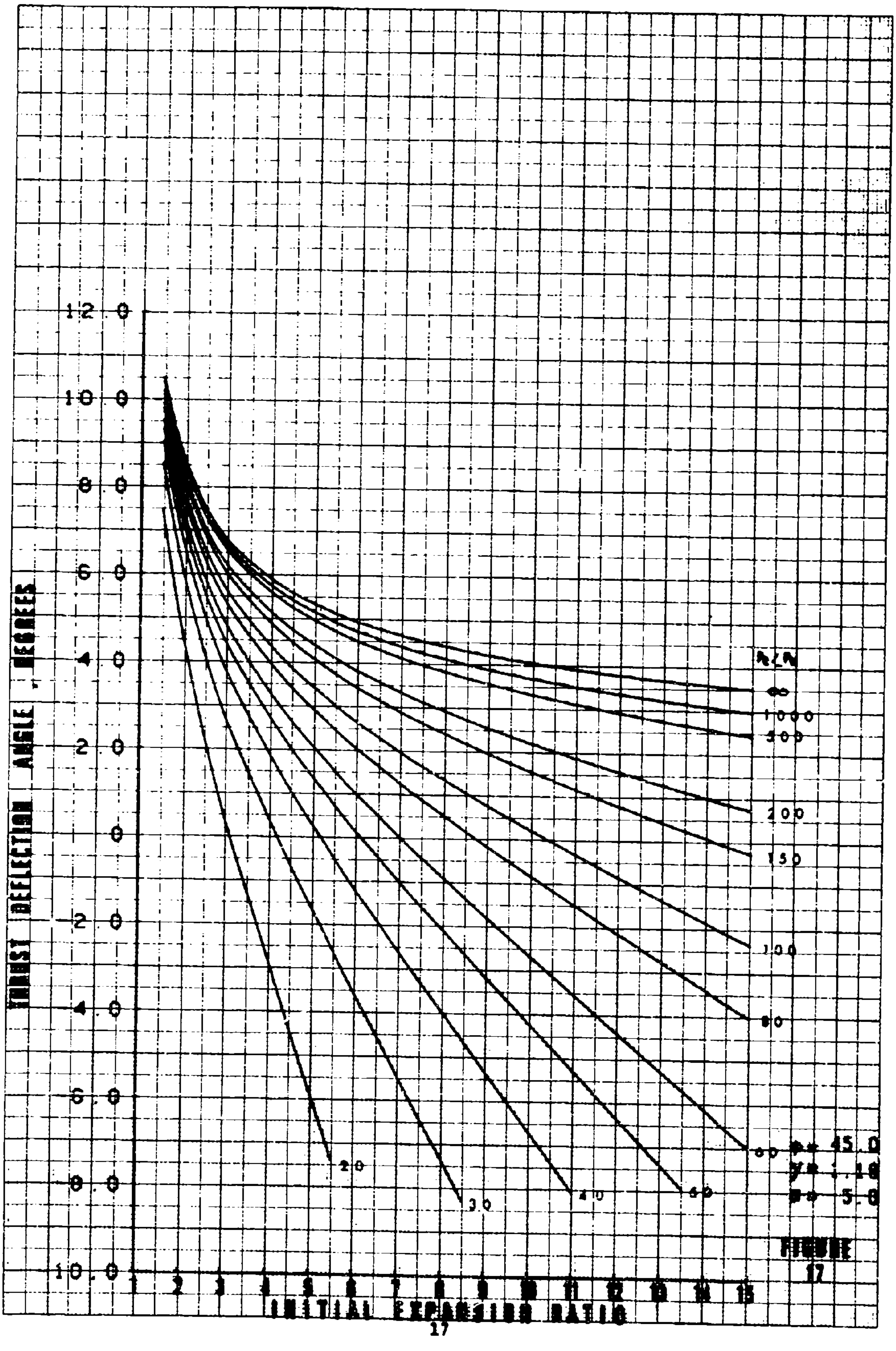

THRUST DEFLECTION ANGLE, DEGREES
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0
-2.0
-4.0
-6.0
-8.0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
Pc/Pa
∞
1000
500
200
150
100
80
60
50
40
30
20
= 40.0
γ = 1.18
5.0

FIGURE 14



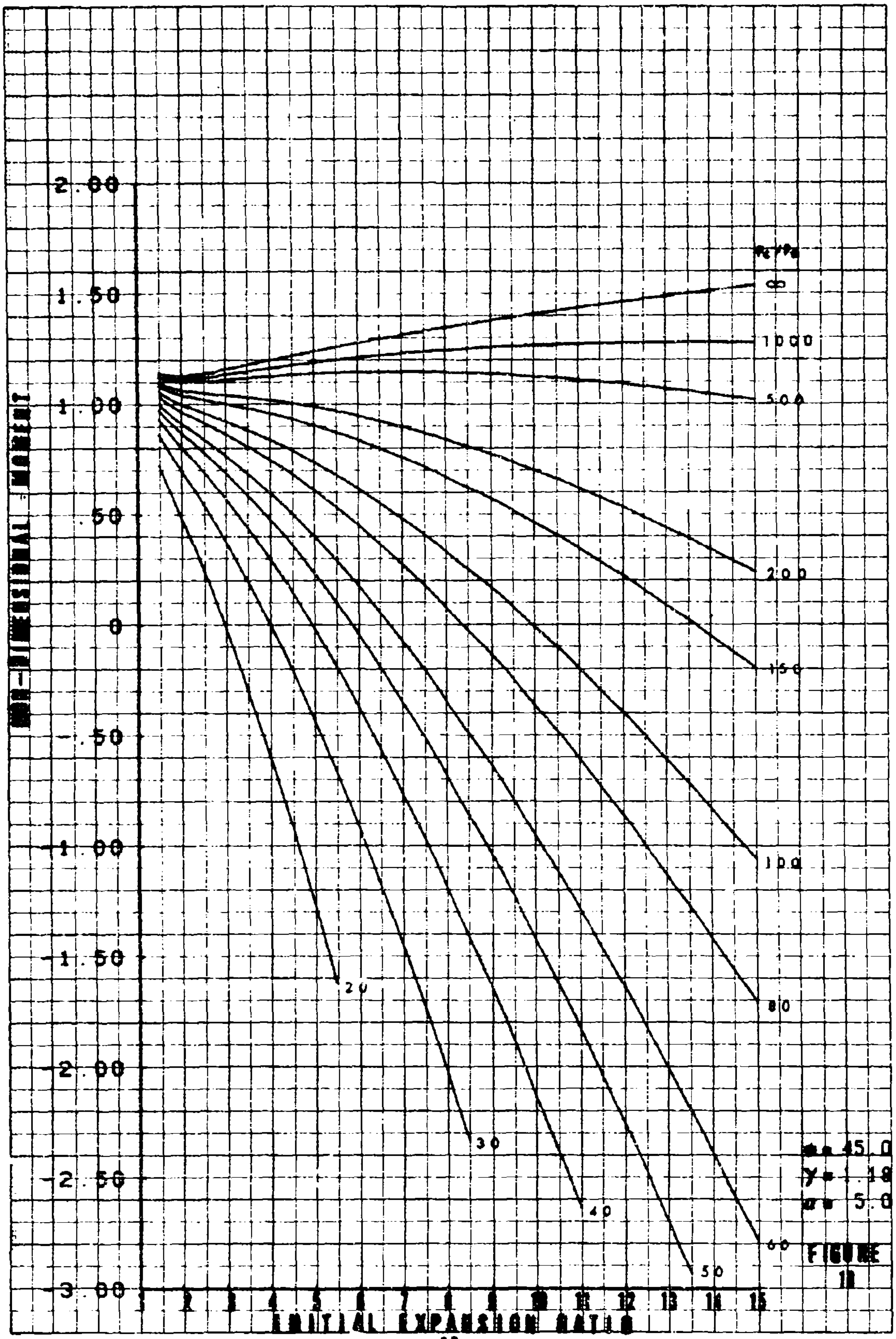
2.00
1.50
1.00
.50
0
-.50
-1.00
-1.50
-2.00
-2.50
-3.00
NON-DIMENSIONAL MOMENT
INITIAL EXPANSION RATIO
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
1000
500
200
150
100
80
60
50
40
30
20
FIGURE 15

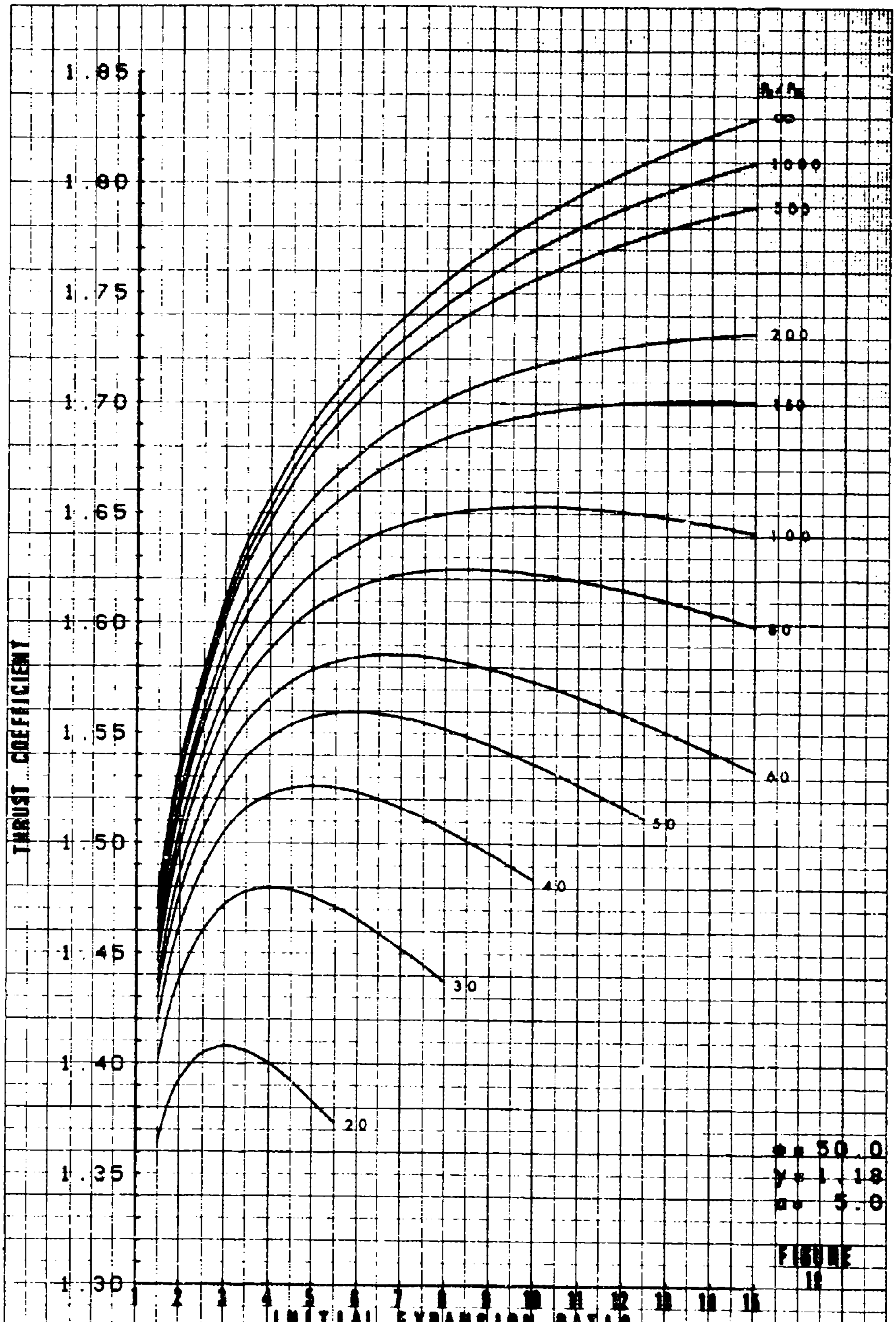

THRUST COEFFICIENT
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
1000
500
200
150
100
80
60
50
40
30
20
= 45.0
= 1.18
= 5.0
FIGURE
16
INITIAL EXPANSION RATIO

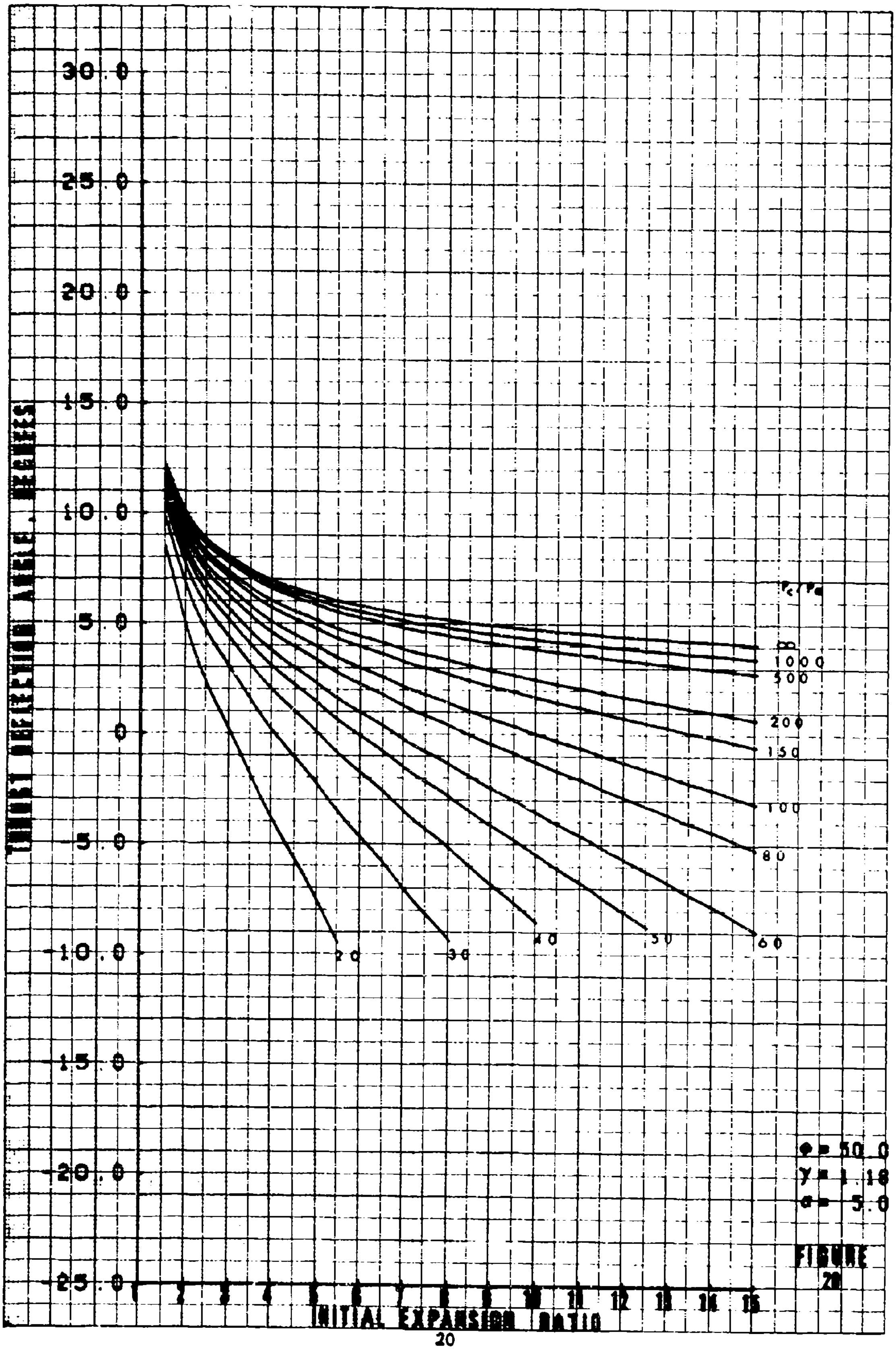


THRUST DEFLECTION ANGLE, DEGREES
12.0
10.0
8.0
6.0
4.0
2.0
0
-2.0
-4.0
-6.0
-8.0
-10.0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
INITIAL EXPANSION RATIO
1000
500
200
150
100
80
60
50
40
30
20

FIGURE 17


NON-DIMENSIONAL MOMENT
INITIAL EXPANSION RATIO
2.00
1.50
1.00
.50
0
-.50
-1.00
-1.50
-2.00
-2.50
-3.00
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
Pc/Pa
∞
1000
500
200
150
100
80
60
50
40
30
20
45.0
5.0
FIGURE


THRUST COEFFICIENT
INITIAL EXPANSION RATIO
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
∞
1000
500
200
100
80
60
50
40
30
20
= 50.0
γ = 1.18
= 5.0
FIGURE


THRUST DEFLECTION ANGLE, DEGREES
INITIAL EXPANSION RATIO
30.0
25.0
20.0
15.0
10.0
5.0
0
-5.0
-10.0
-15.0
-20.0
-25.0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
P_c/P_a
∞
1000
500
200
150
100
80
60
50
40
30
20
ϕ = 50.0
γ = 1.18
α = 5.0
FIGURE 20

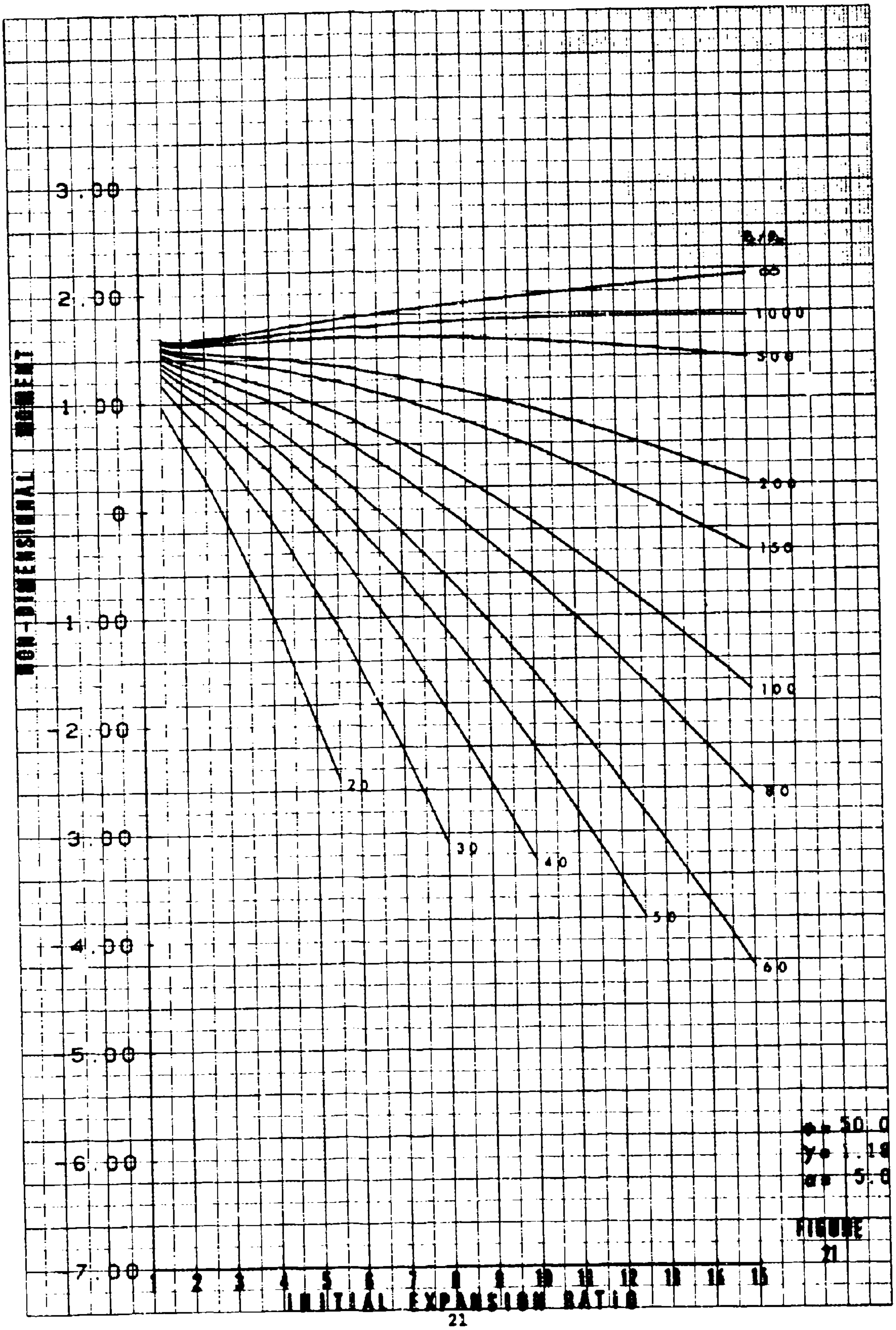
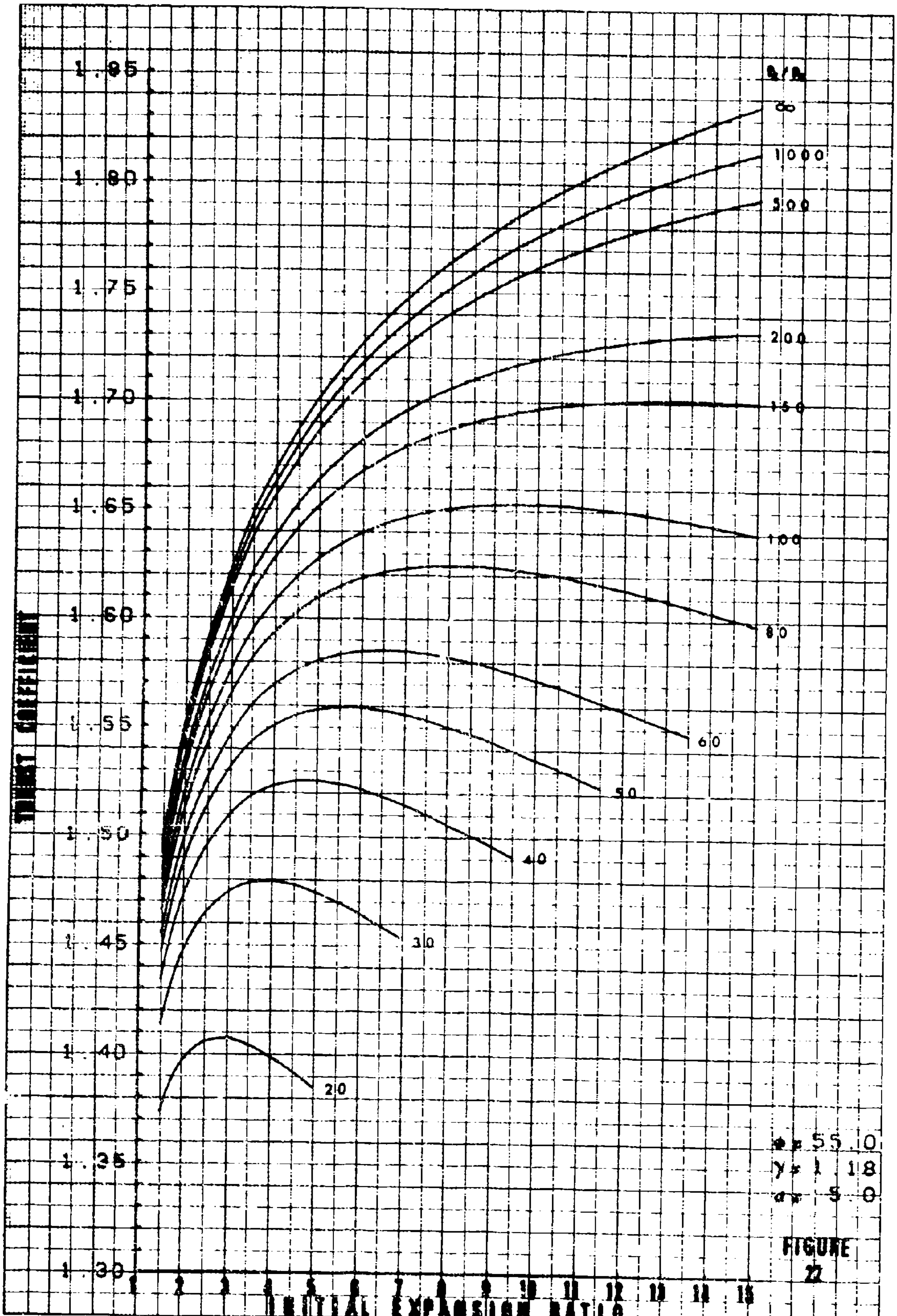

NON-DIMENSIONAL MOMENT
3.00
2.00
1.00
0
-1.00
-2.00
-3.00
-4.00
-5.00
-6.00
-7.00
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
INITIAL EXPANSION RATIO
1000
500
200
150
100
80
60
50
40
30
20

FIGURE 21


1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
THRUST COEFFICIENT
∞
1000
500
200
150
100
80
60
50
40
30
20
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
γ = 1.18
α = 5.0
FIGURE 22

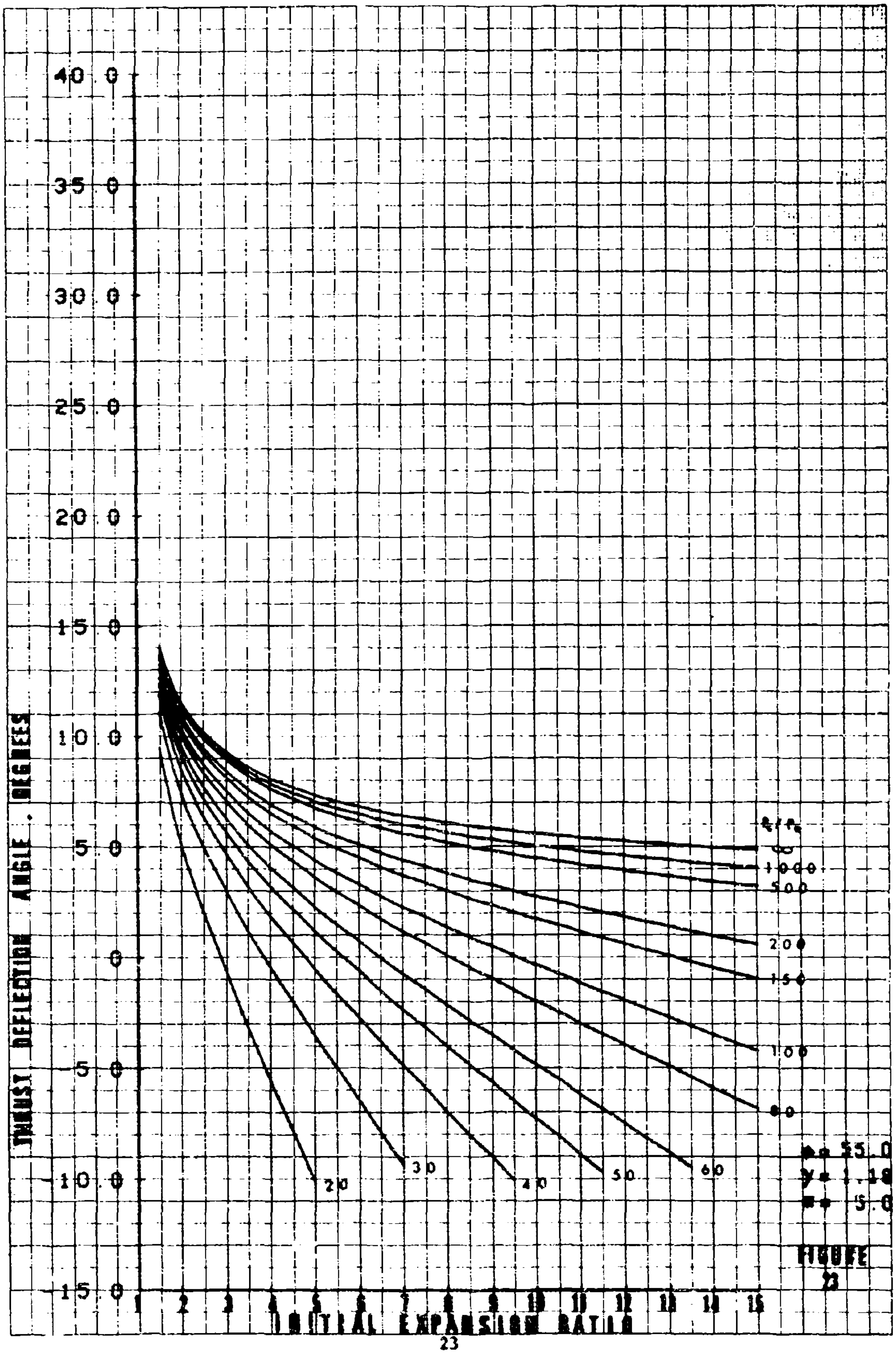
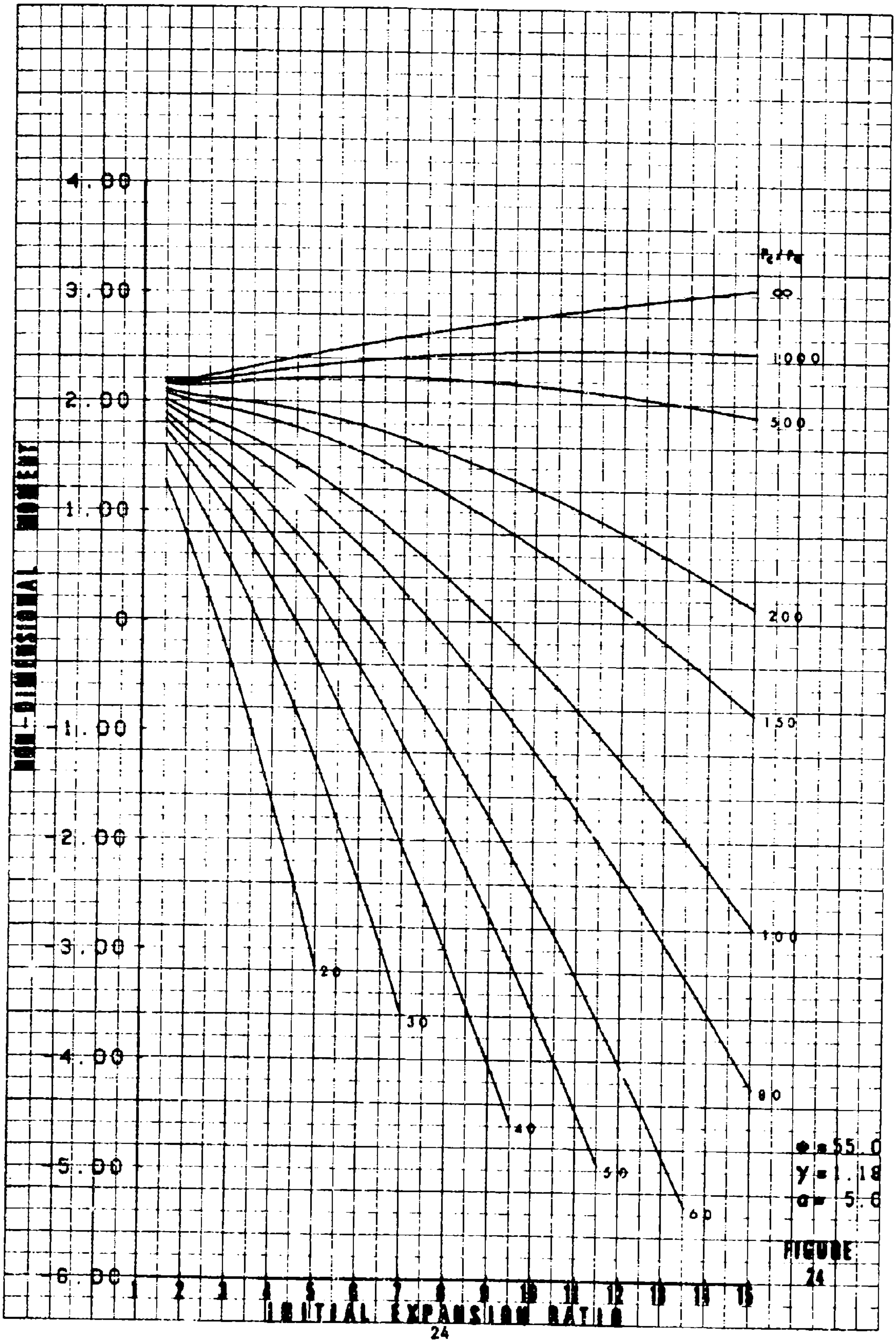
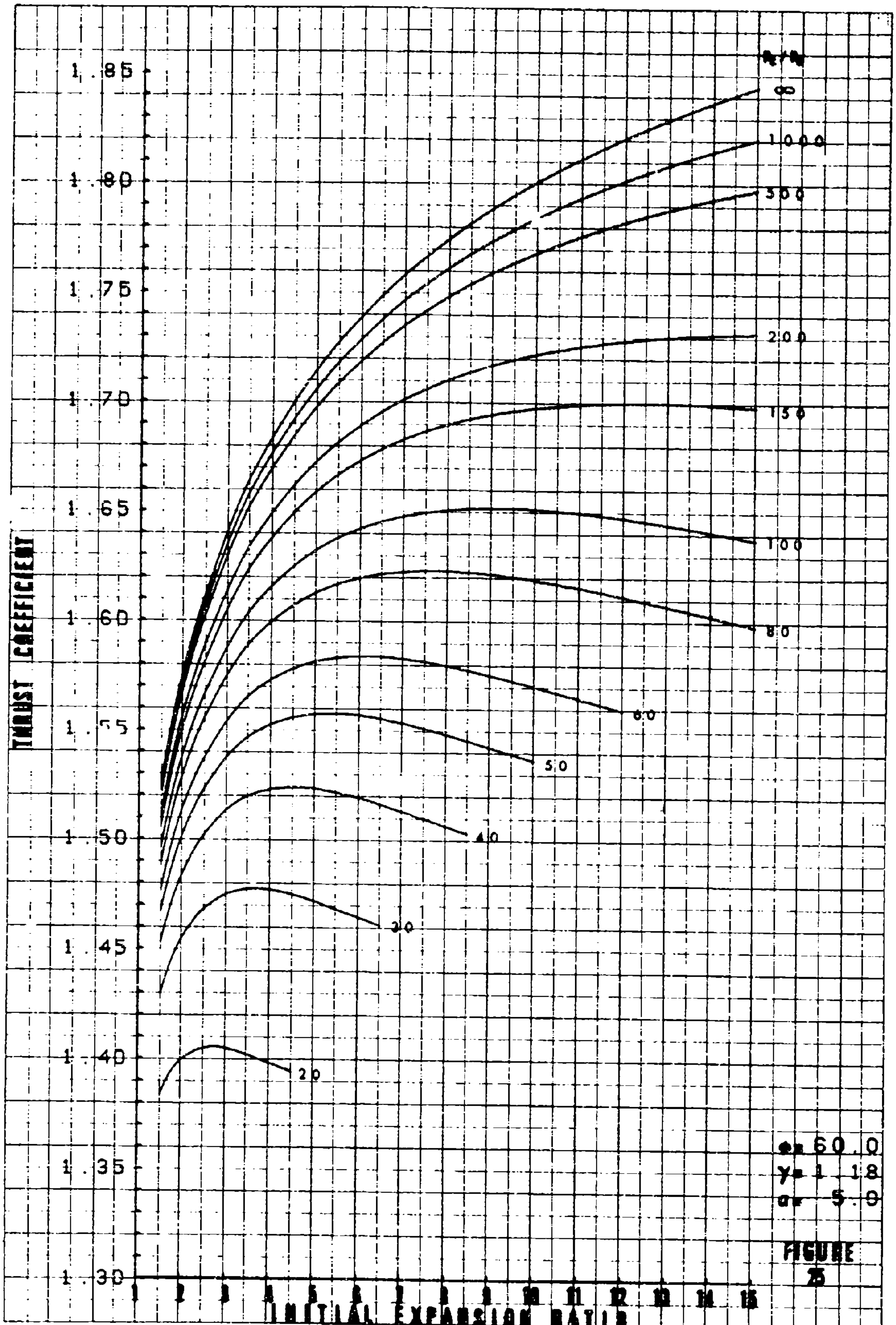

40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0
-5.0
-10.0
-15.0
THRUST DEFLECTION ANGLE, DEGREES
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
∞
1000
500
200
150
100
80
60
50
40
30
20

FIGURE 23

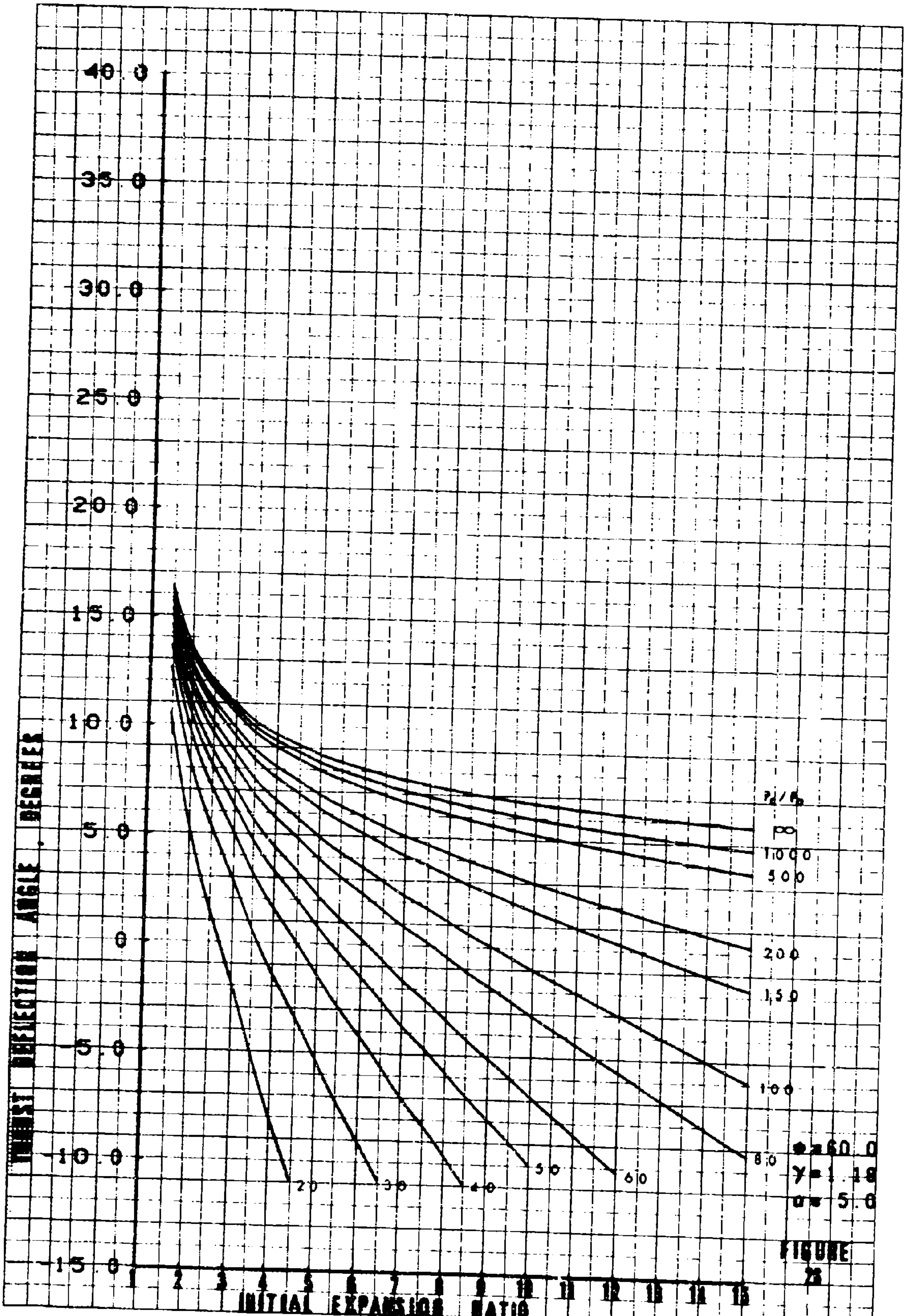


4.00
3.00
2.00
1.00
0
-1.00
-2.00
-3.00
-4.00
-5.00
-6.00
NON-DIMENSIONAL MOMENT
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
INITIAL EXPANSION RATIO
P_c/P_a
∞
1000
500
200
150
100
80
20
30
40
50
60
φ = 55.0
γ = 1.18
α = 5.6
FIGURE
24



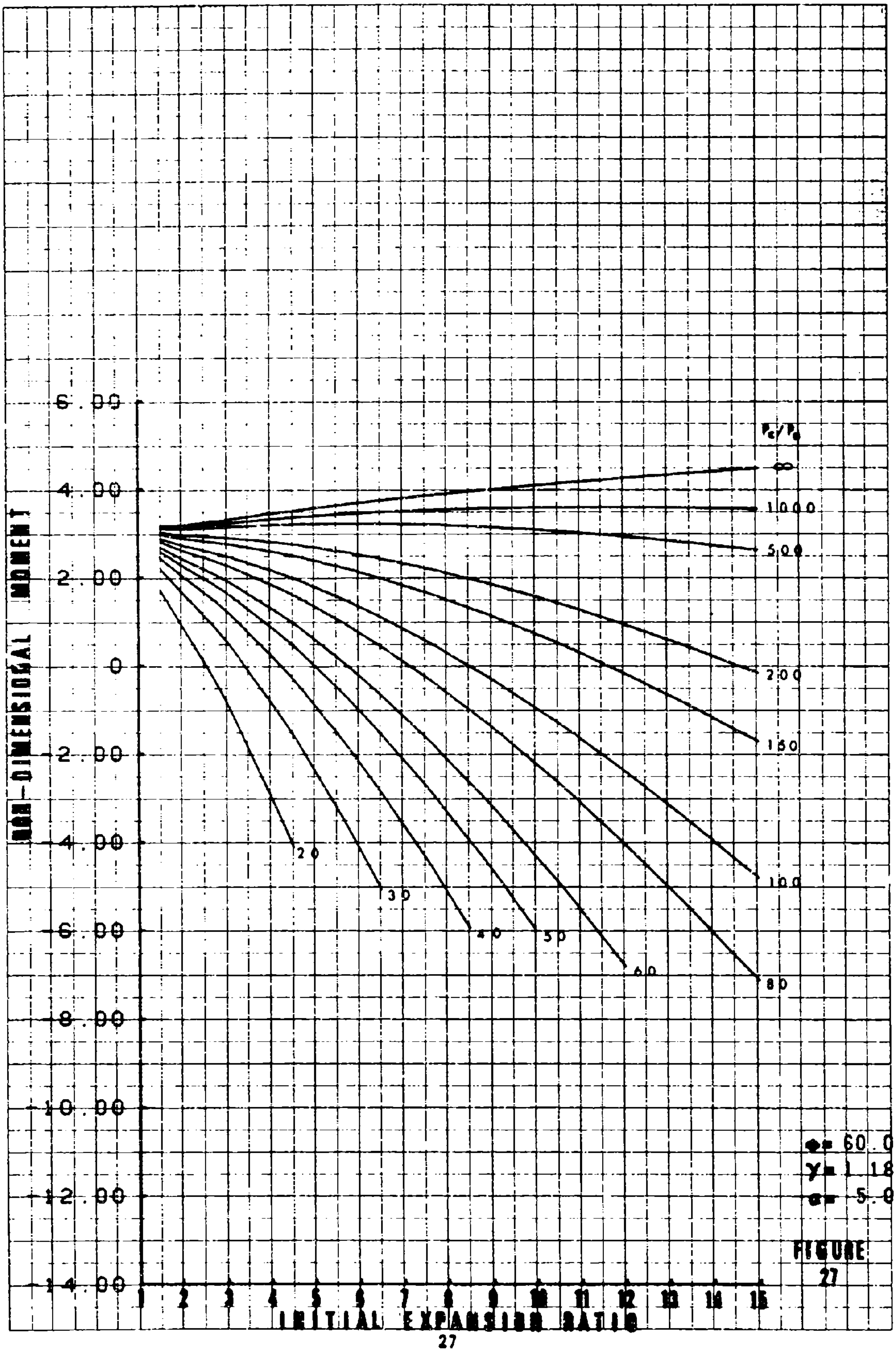
THRUST COEFFICIENT
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
P_c/P_e
∞
1000
500
200
150
100
80
60
50
40
30
20
ϕ= 60.0
γ= 1.18
α= 5.0

FIGURE 25



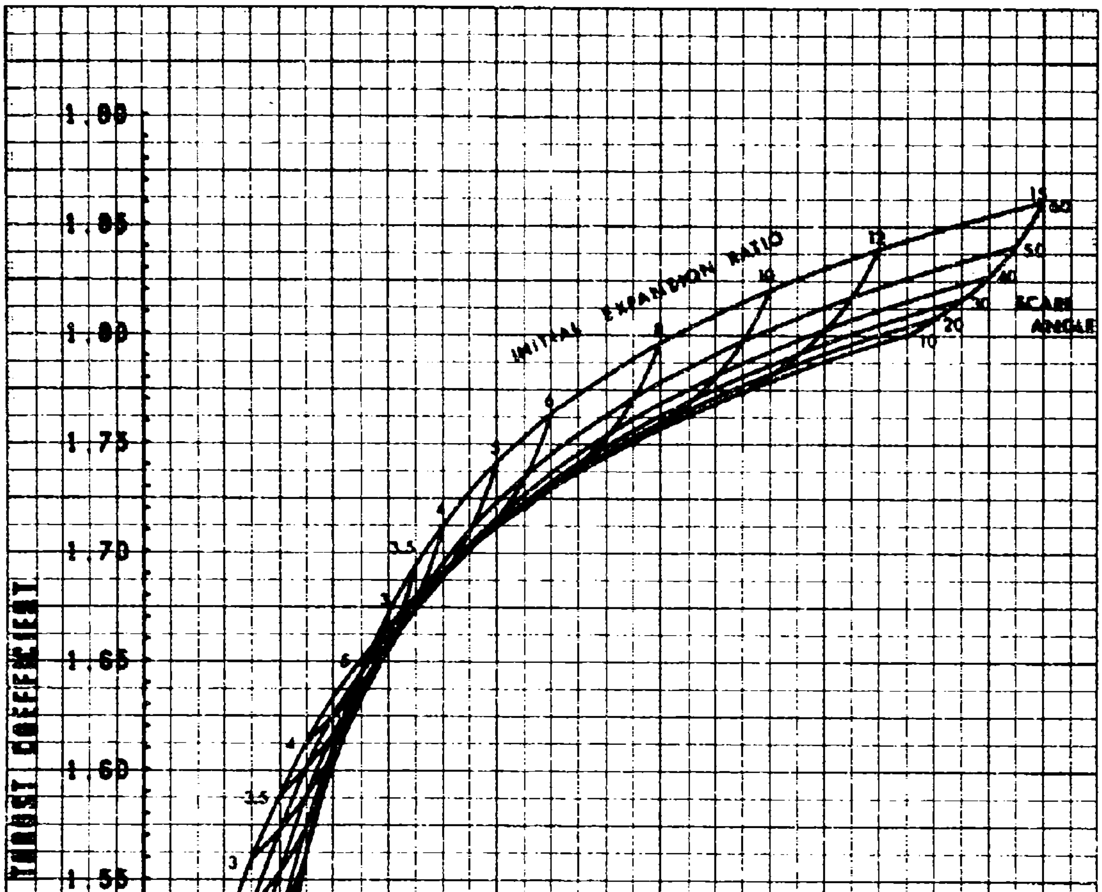
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0
-5.0
-10.0
-15.0
THRUST DEFLECTION ANGLE, DEGREES
INITIAL EXPANSION RATIO
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
P_c/P_b
∞
1000
500
200
150
100
80
60
50
40
30
20

FIGURE 23



6.00
4.00
2.00
0
-2.00
-4.00
-6.00
-8.00
-10.00
-12.00
-14.00
NON-DIMENSIONAL MOMENT
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
Pc/Pa
∞
1000
500
200
150
100
80
60
50
40
30
20
Φ= 60.0
γ= 1.18
α= 5.0

FIGURE 27



THRUST COEFFICIENT
1.80
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
INITIAL EXPANSION RATIO
SCARF ANGLE
$R_c = 0.0$
$\gamma = 1.18$
$\sigma = 10.0$

FIGURE 21

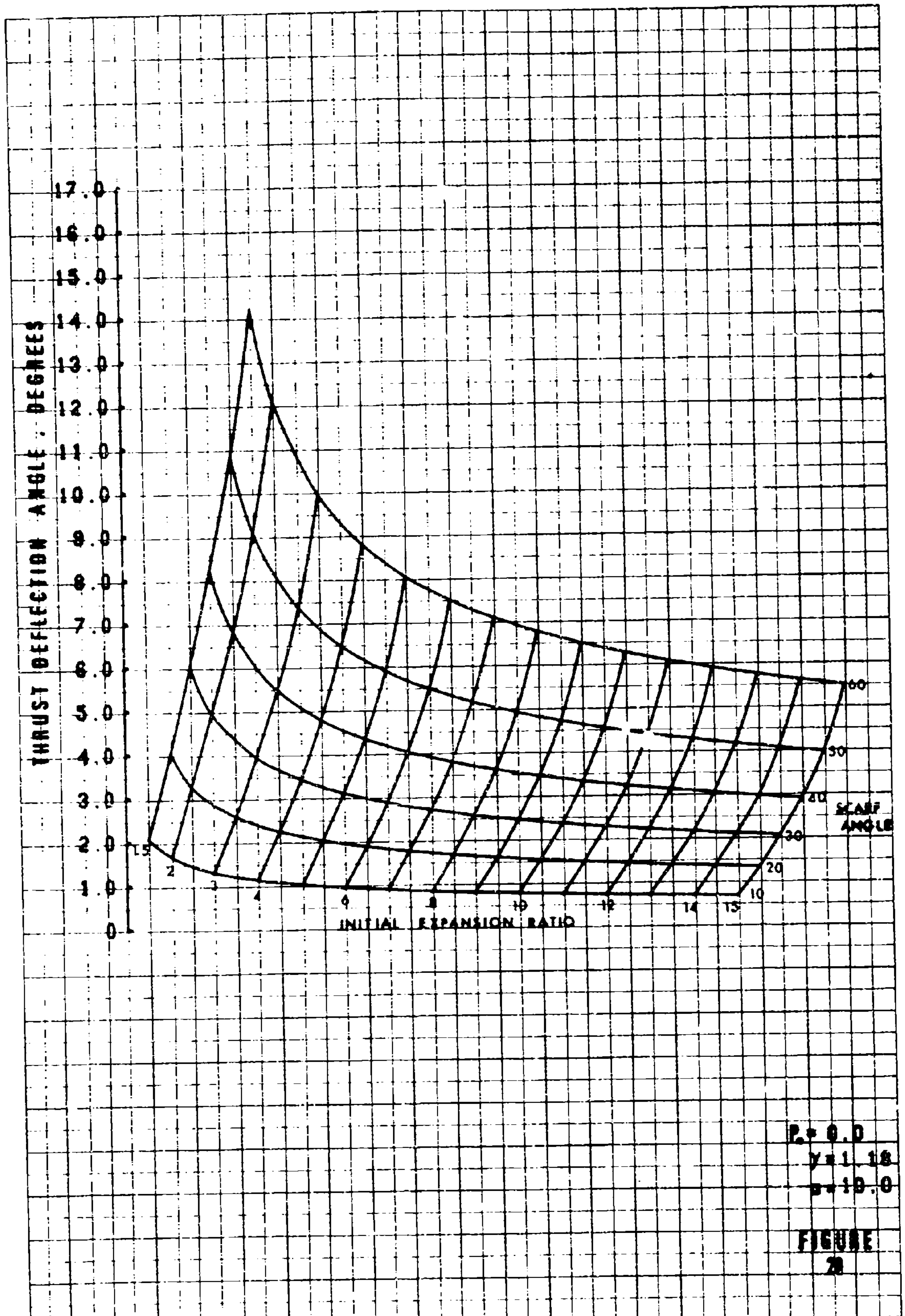
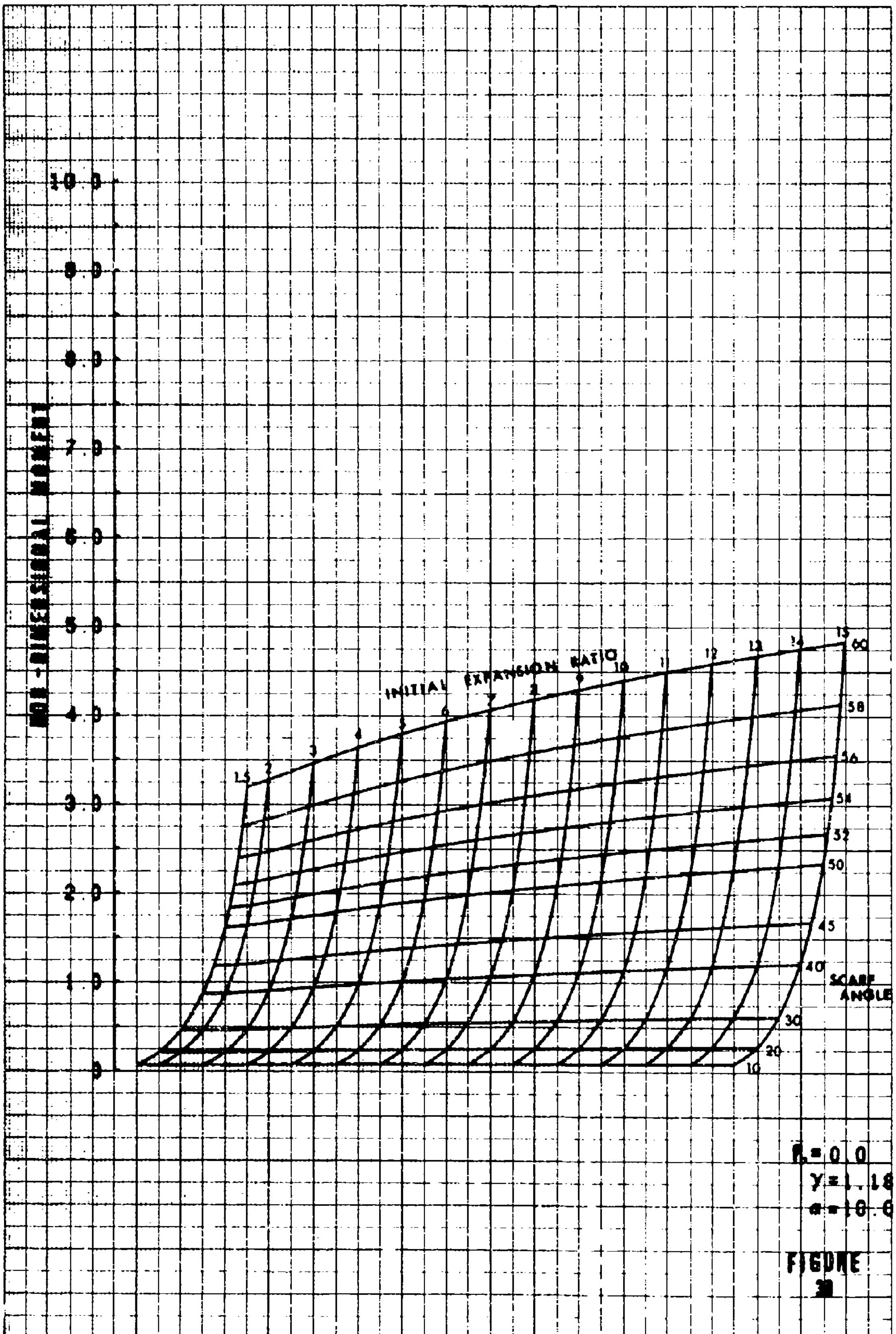

THRUST DEFLECTION ANGLE, DEGREES
17.0
16.0
15.0
14.0
13.0
12.0
11.0
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
1.5
2
3
4
6
8
10
12
14
15
INITIAL EXPANSION RATIO
10
20
30
40
50
60
SCARF ANGLE
$P_a = 0.0$
$\gamma = 1.18$
$\rho = 10.0$

FIGURE 2[illegible]


NON-DIMENSIONAL MOMENT
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
INITIAL EXPANSION RATIO
1.5
2
3
4
5
6
7
8
9
10
11
12
13
14
15
60
58
56
54
52
50
45
40
30
20
10
SCARF ANGLE
Pa = 0.0
γ = 1.18
a = 18.6
FIGURE

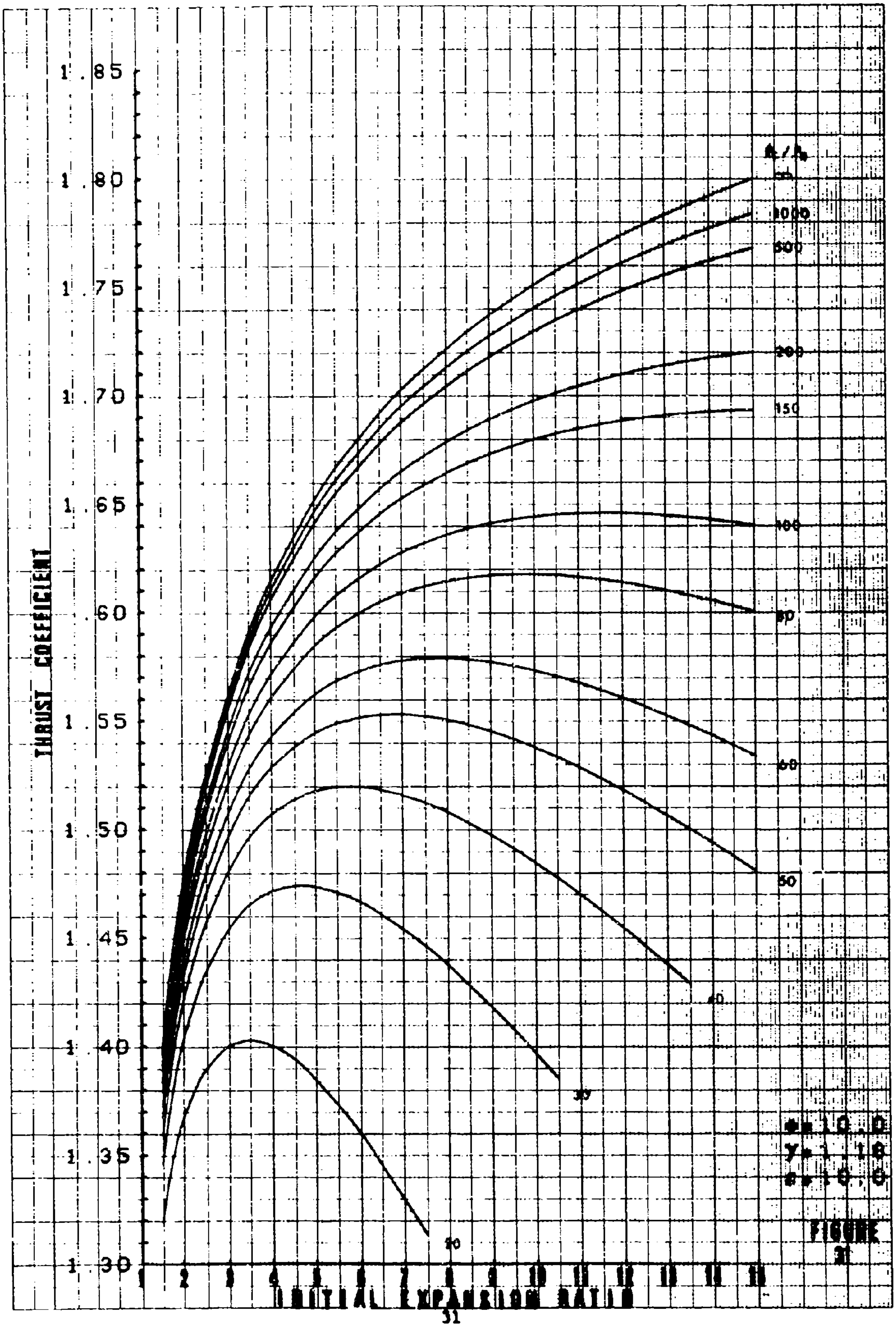

THRUST COEFFICIENT
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
INITIAL EXPANSION RATIO
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
1000
500
200
150
100
80
60
50
40
30
20
ε = 10.0
γ = 1.18

FIGURE 31

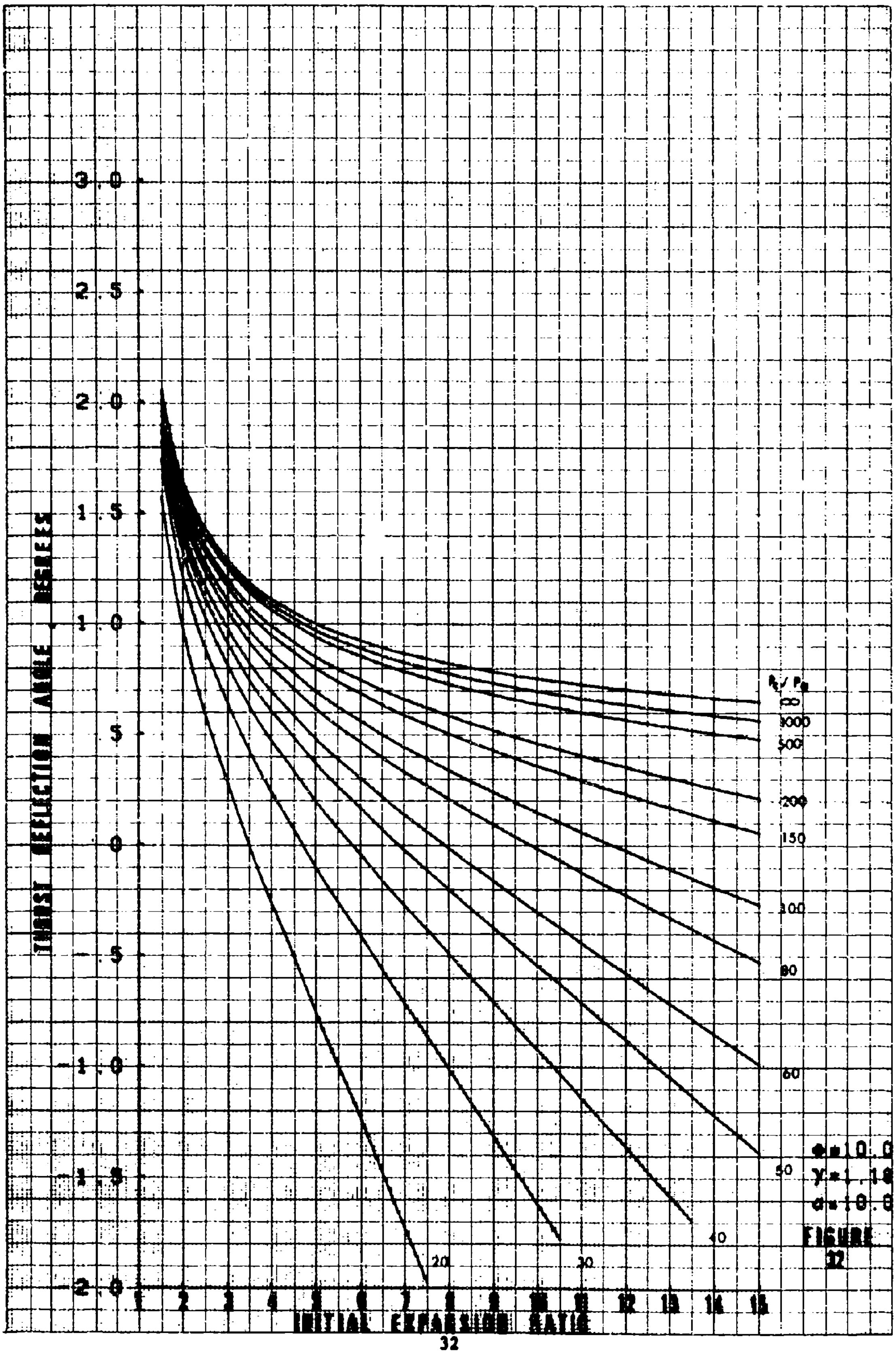
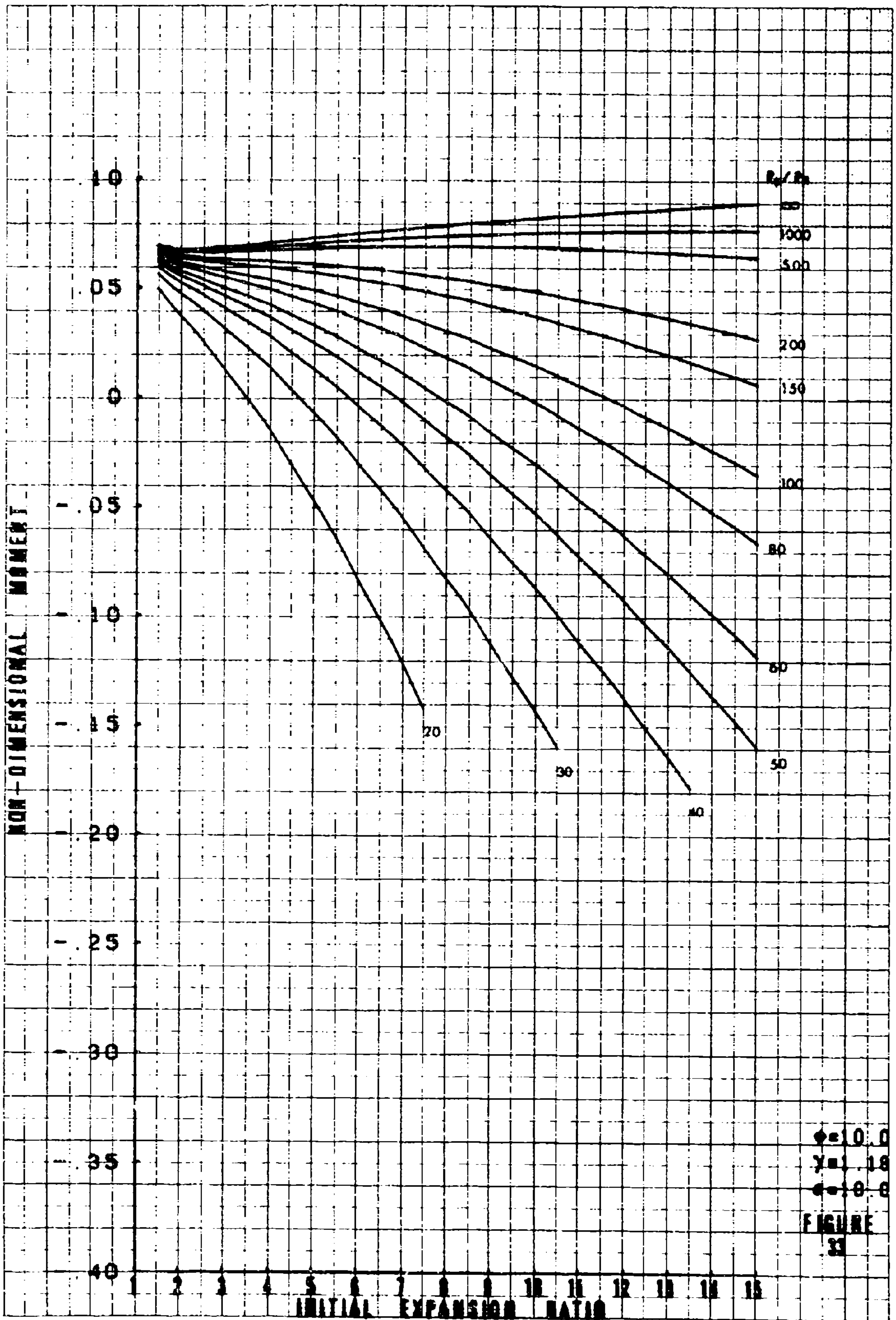

THRUST DEFLECTION ANGLE - DEGREES
3.0
2.5
2.0
1.5
1.0
.5
0
-.5
-1.0
-1.5
-2.0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
P_t/P_a
∞
500
200
150
100
80
60
50
40
30
20

FIGURE 32


NON-DIMENSIONAL MOMENT
INITIAL EXPANSION RATIO
.10
.05
0
-.05
-.10
-.15
-.20
-.25
-.30
-.35
-.40
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
1000
500
200
150
100
80
60
50
40
30
20

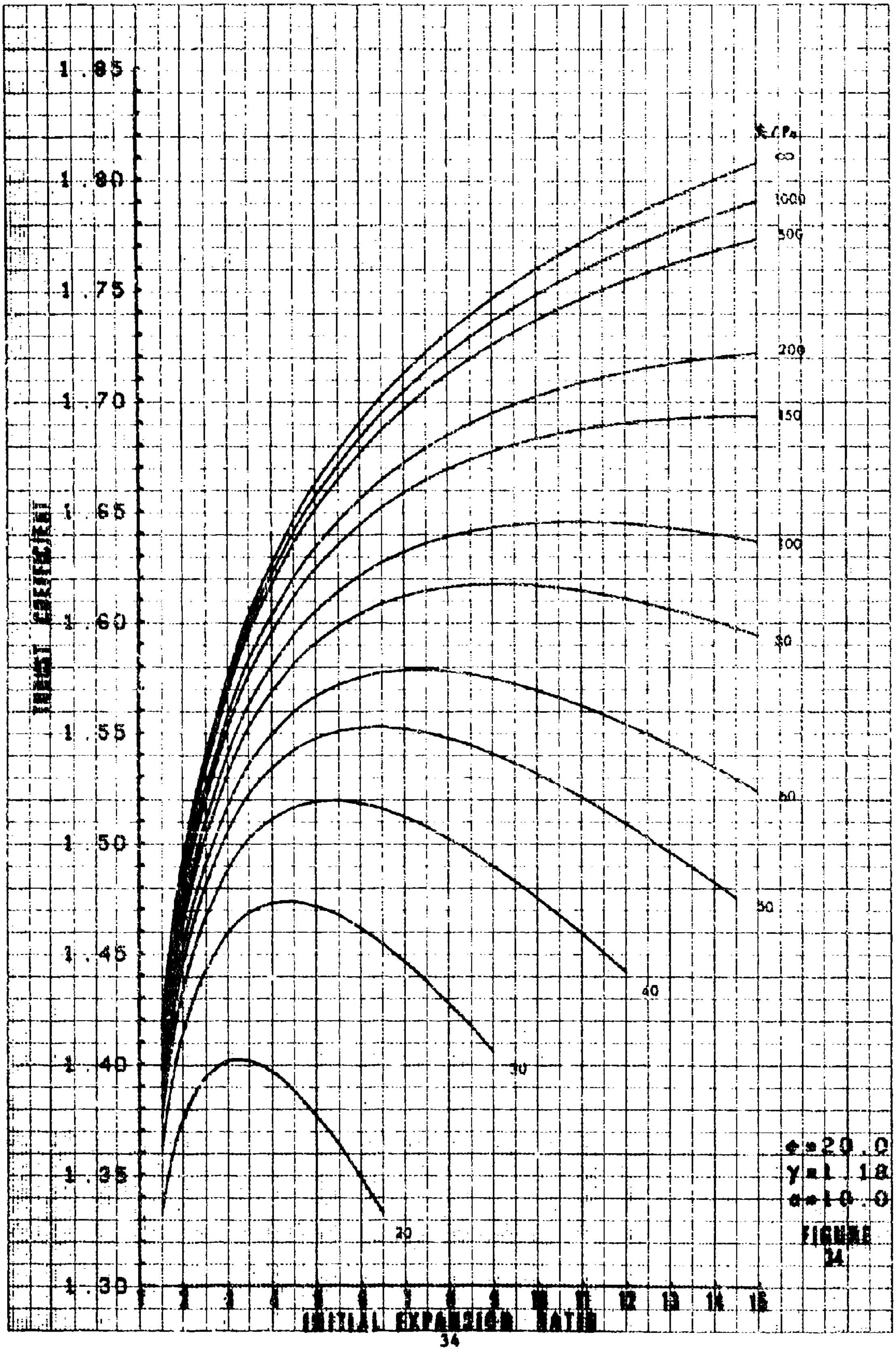
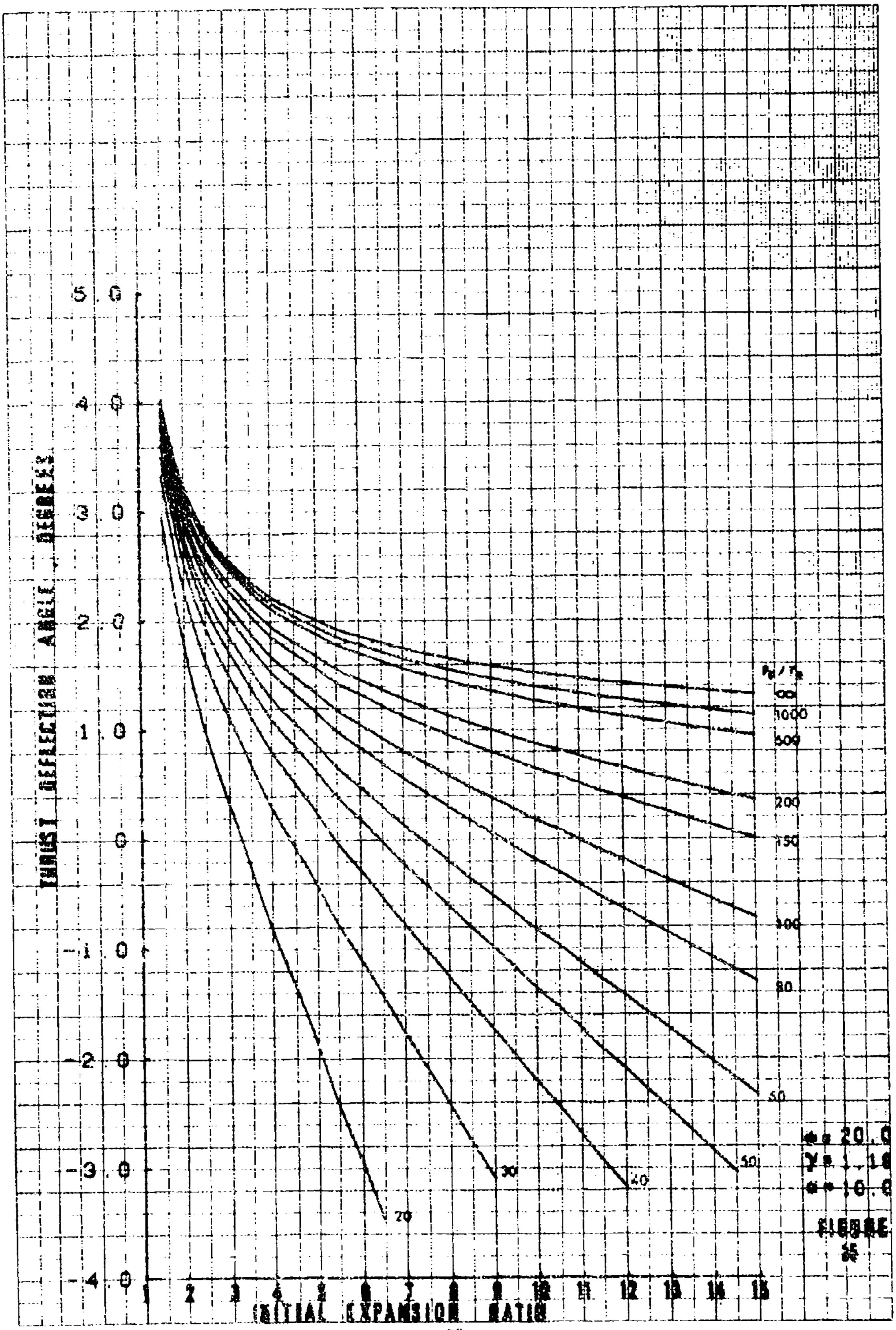
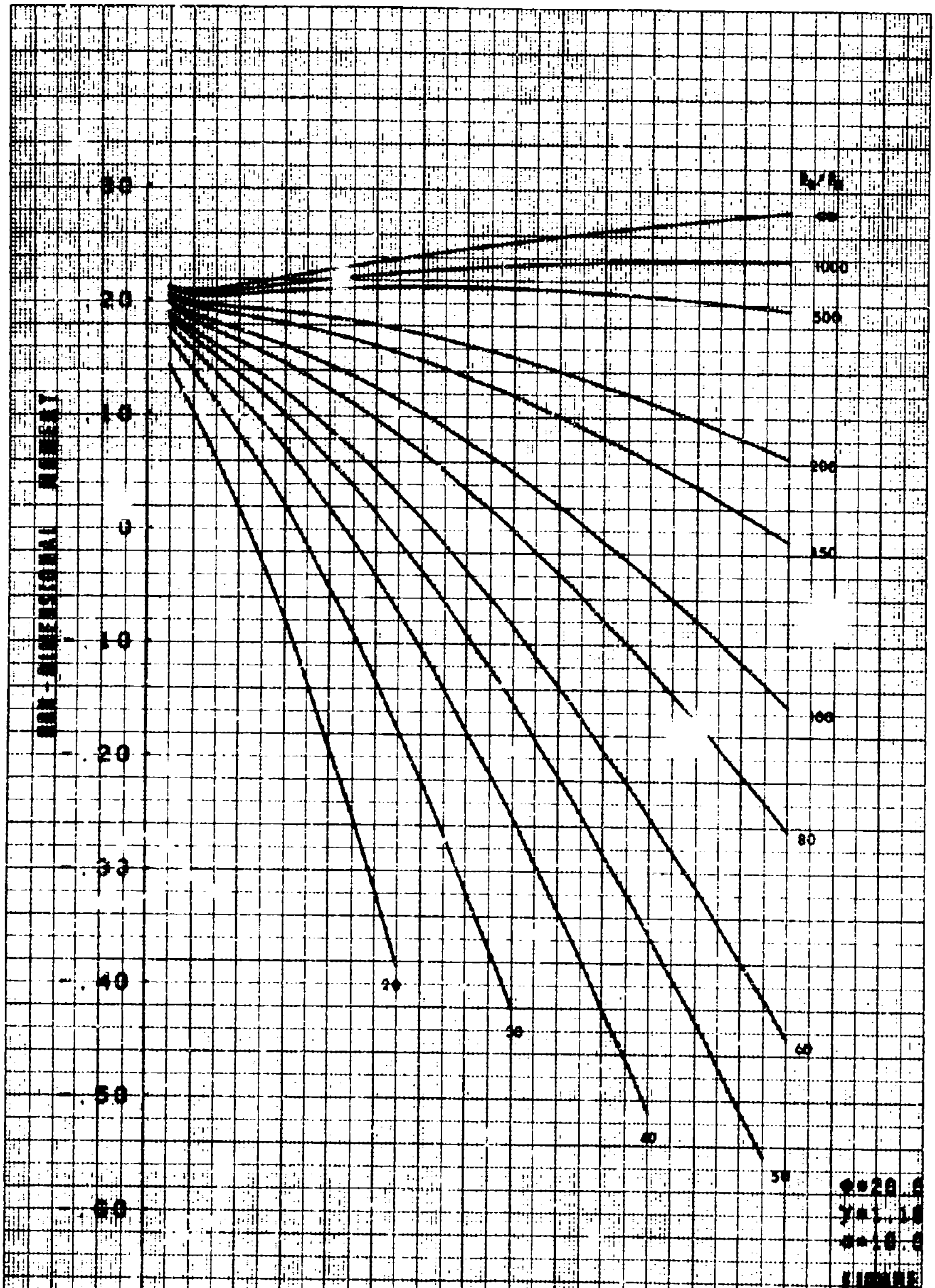
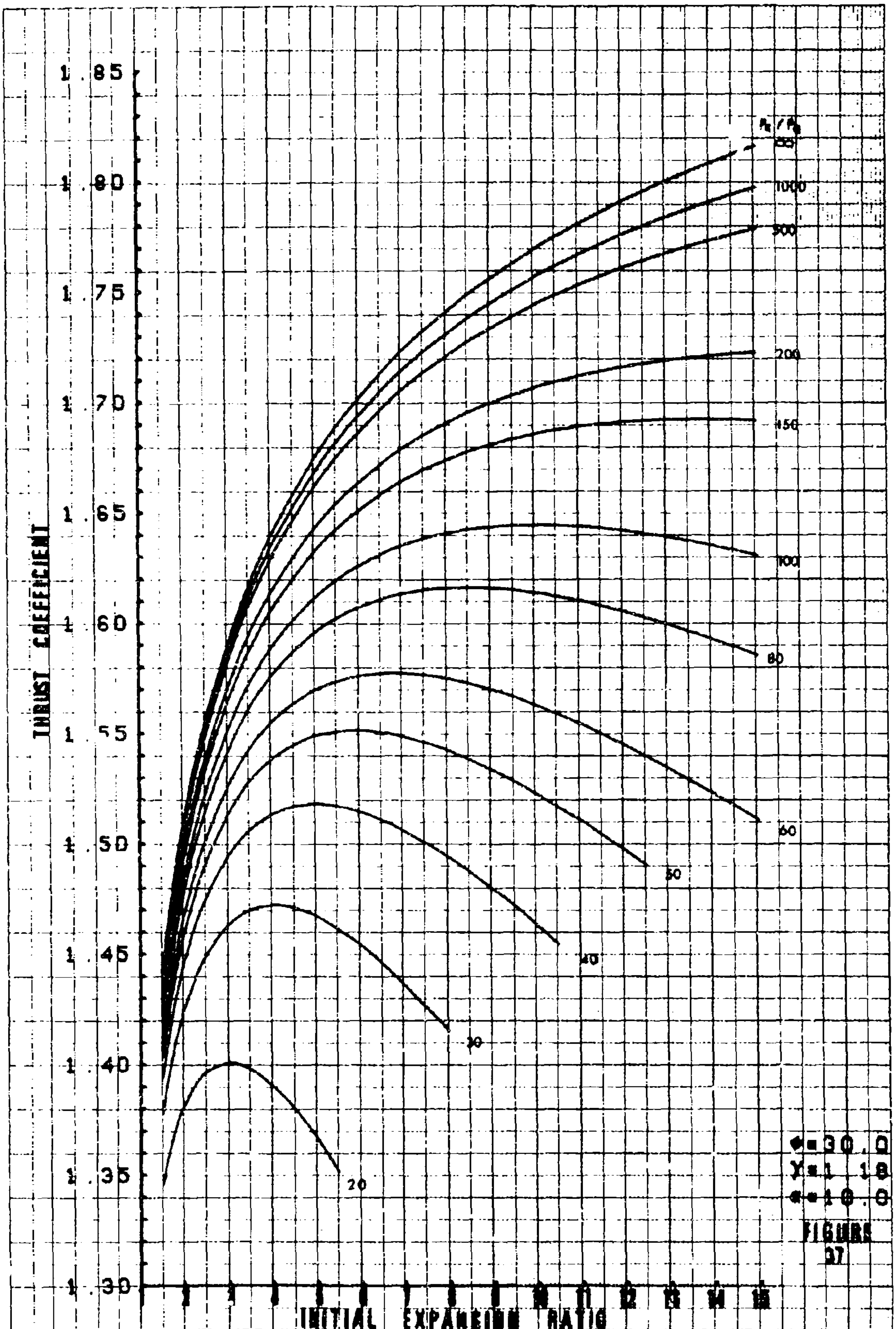

THRUST COEFFICIENT
INITIAL EXPANSION RATIO
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
∞
1000
500
200
150
100
80
60
50
40
30
20
ε=20.0
γ=1.18
α=10.0

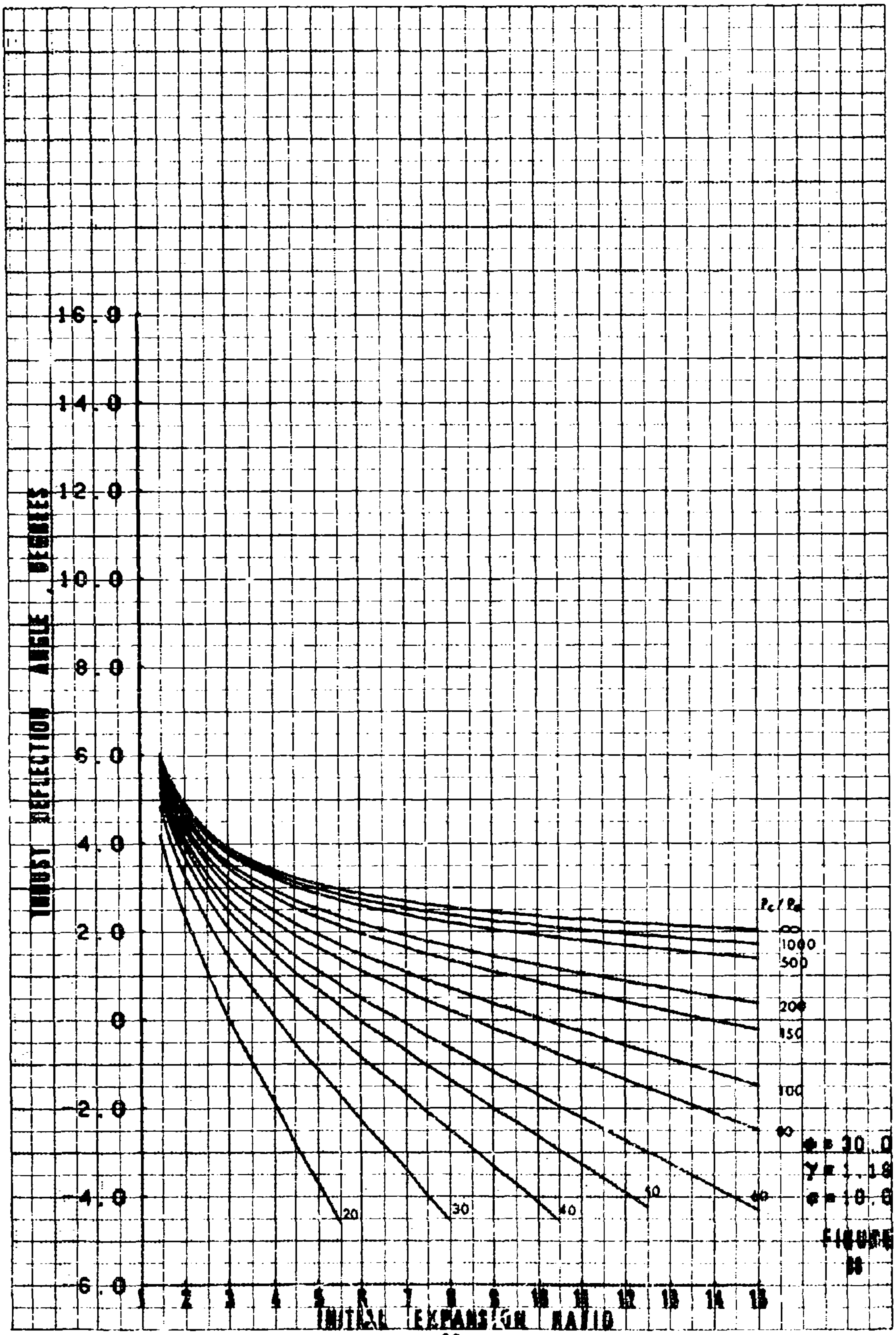
FIGURE 34



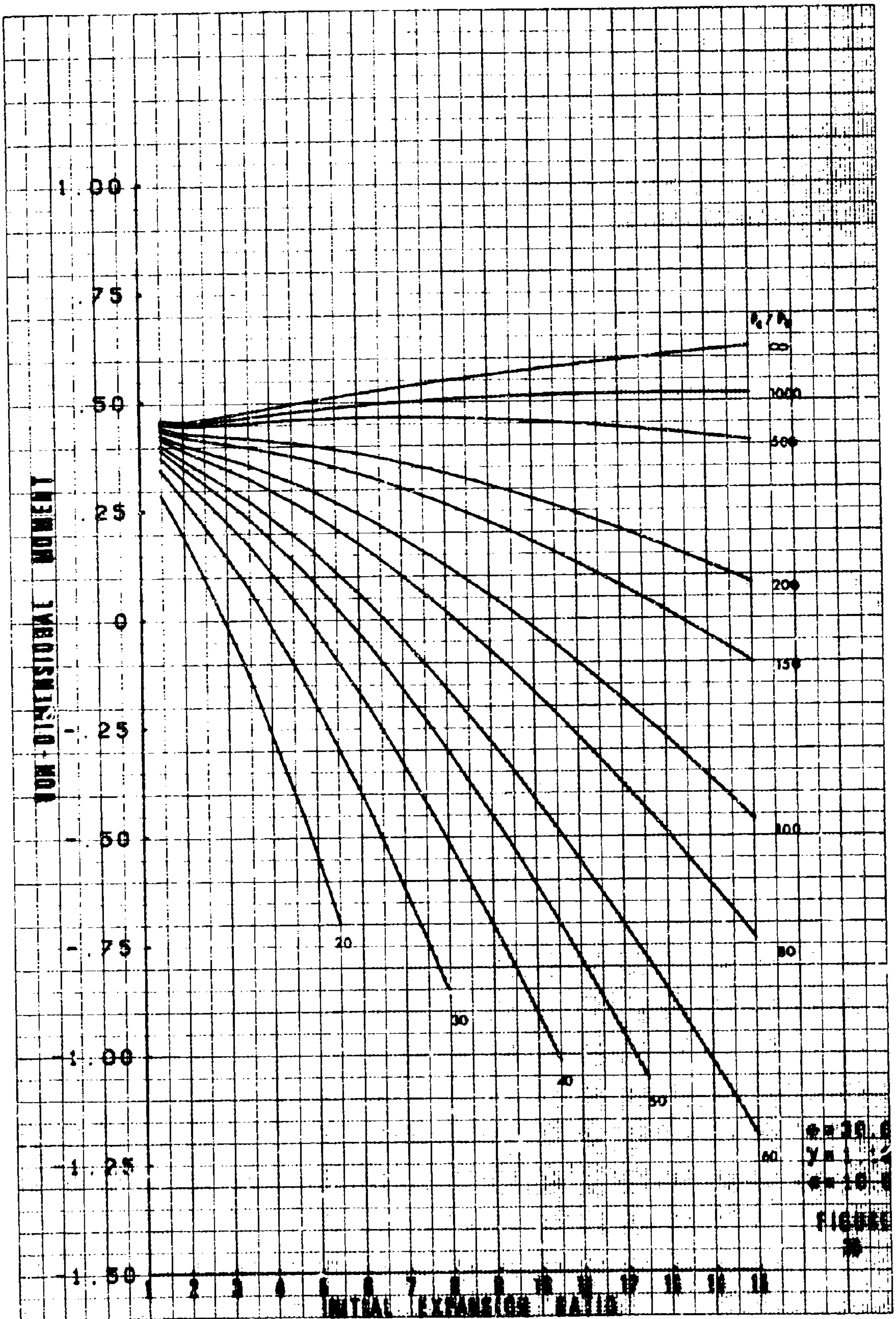
THRUST DEFLECTION ANGLE, DEGREES
5.0
4.0
3.0
2.0
1.0
0
-1.0
-2.0
-3.0
-4.0
INITIAL EXPANSION RATIO
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
1000
200
150
80
50
50
40
30
20

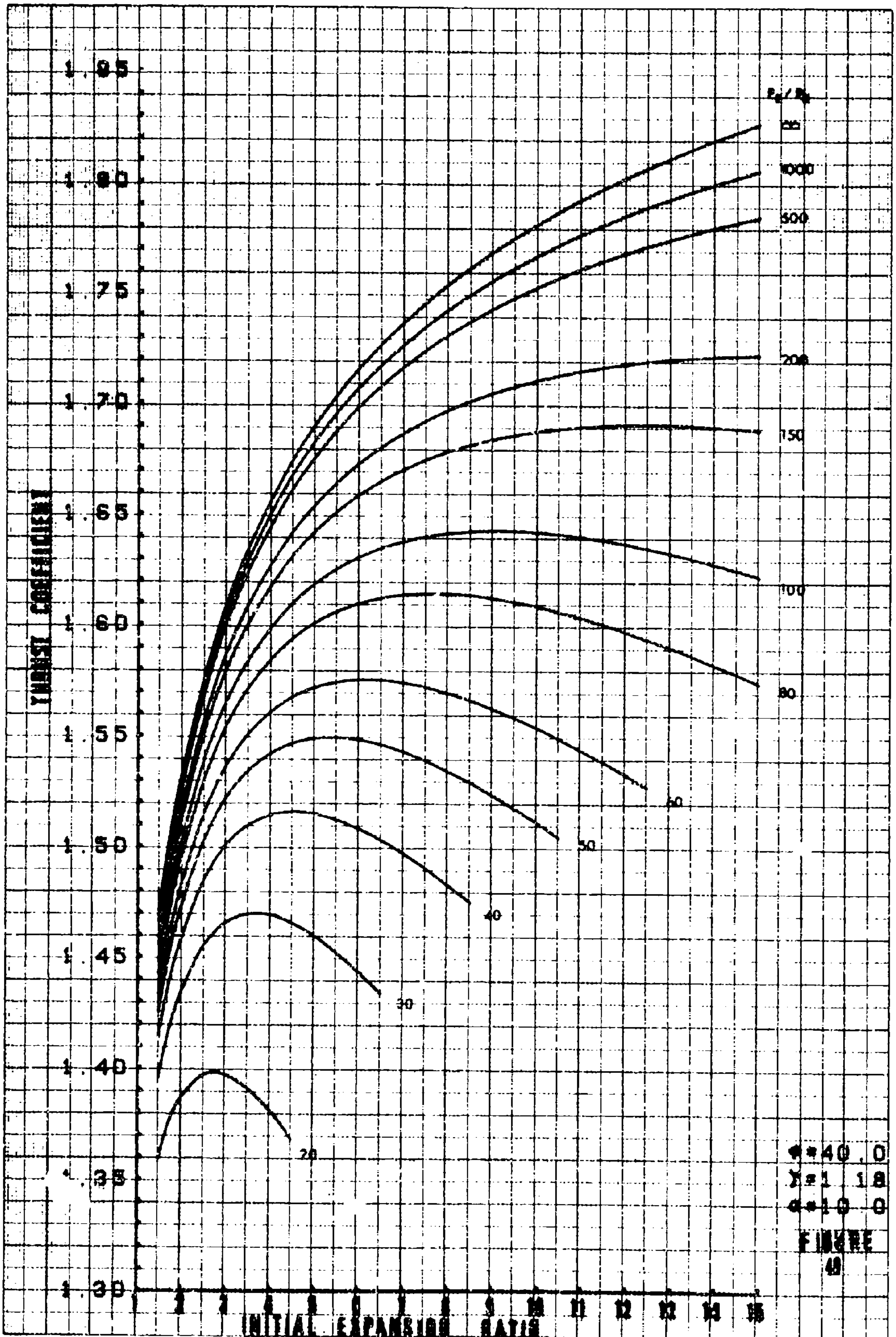



THRUST COEFFICIENT
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
INITIAL EXPANSION RATIO
2 3 4 5 6 7 8 9 10 11 12 13 14 15
P_c/P_a
1000
500
200
150
100
80
60
50
40
30
20
γ=1.18
FIGURE 37



16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0
-2.0
-4.0
-6.0
THRUST DEFLECTION ANGLE, DEGREES
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
INITIAL EXPANSION RATIO
Pc / Pa
∞
1000
500
200
150
100
20
30
40


NON-DIMENSIONAL MOMENT
1.00
.75
.50
.25
0
-.25
-.50
-.75
-1.00
-1.25
-1.50
INITIAL EXPANSION RATIO
∞
1000
500
200
150
100
80
60
50
40
30
20


1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
THRUST COEFFICIENT
INITIAL EXPANSION RATIO
1000
500
200
150
100
80
60
50
40
30
20

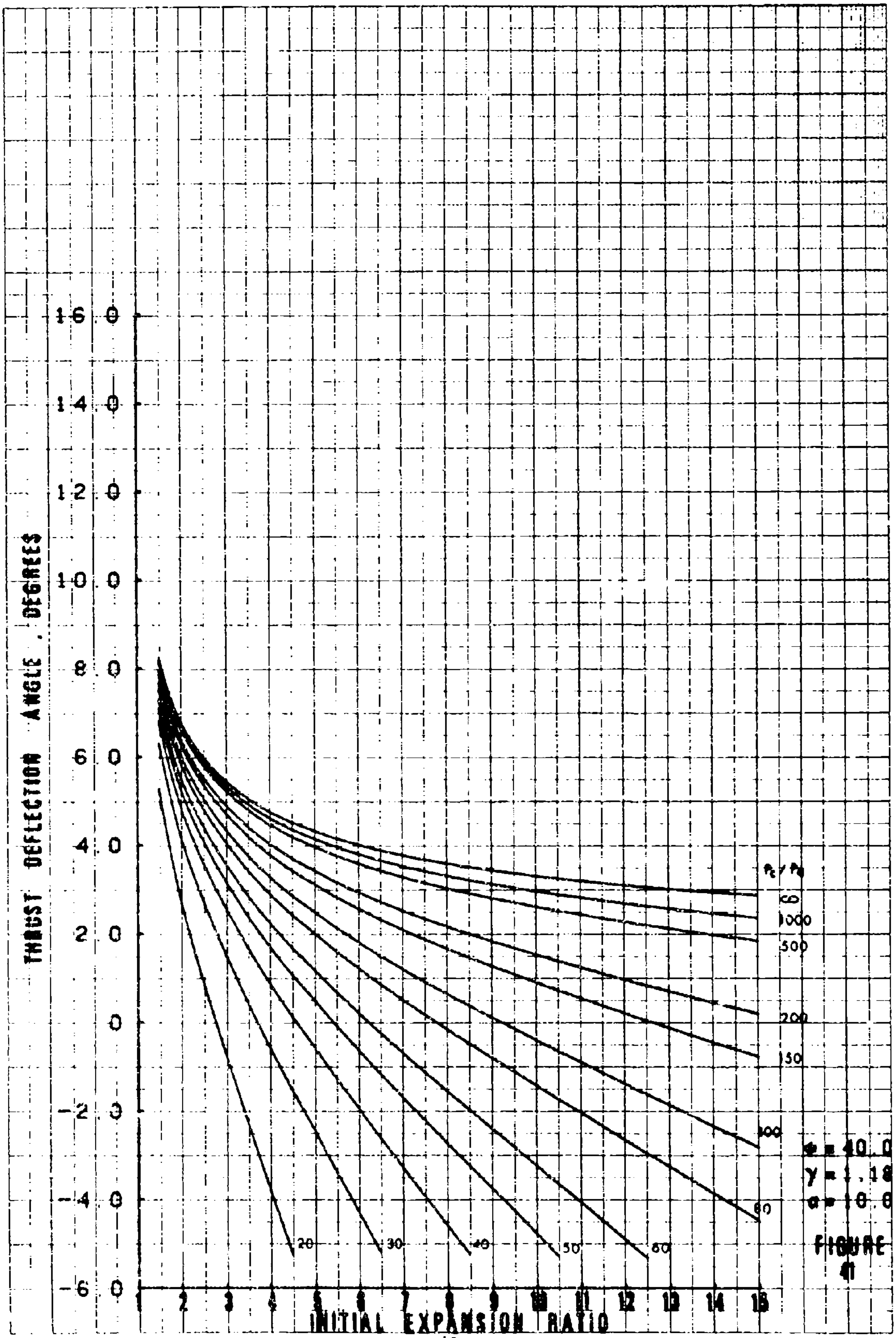

THRUST DEFLECTION ANGLE, DEGREES
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0
-2.0
-4.0
-6.0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
P_c/P_a
∞
1000
500
200
150
100
80
60
50
40
30
20
φ = 40.0
γ = 1.18
α = 10.0

FIGURE 41

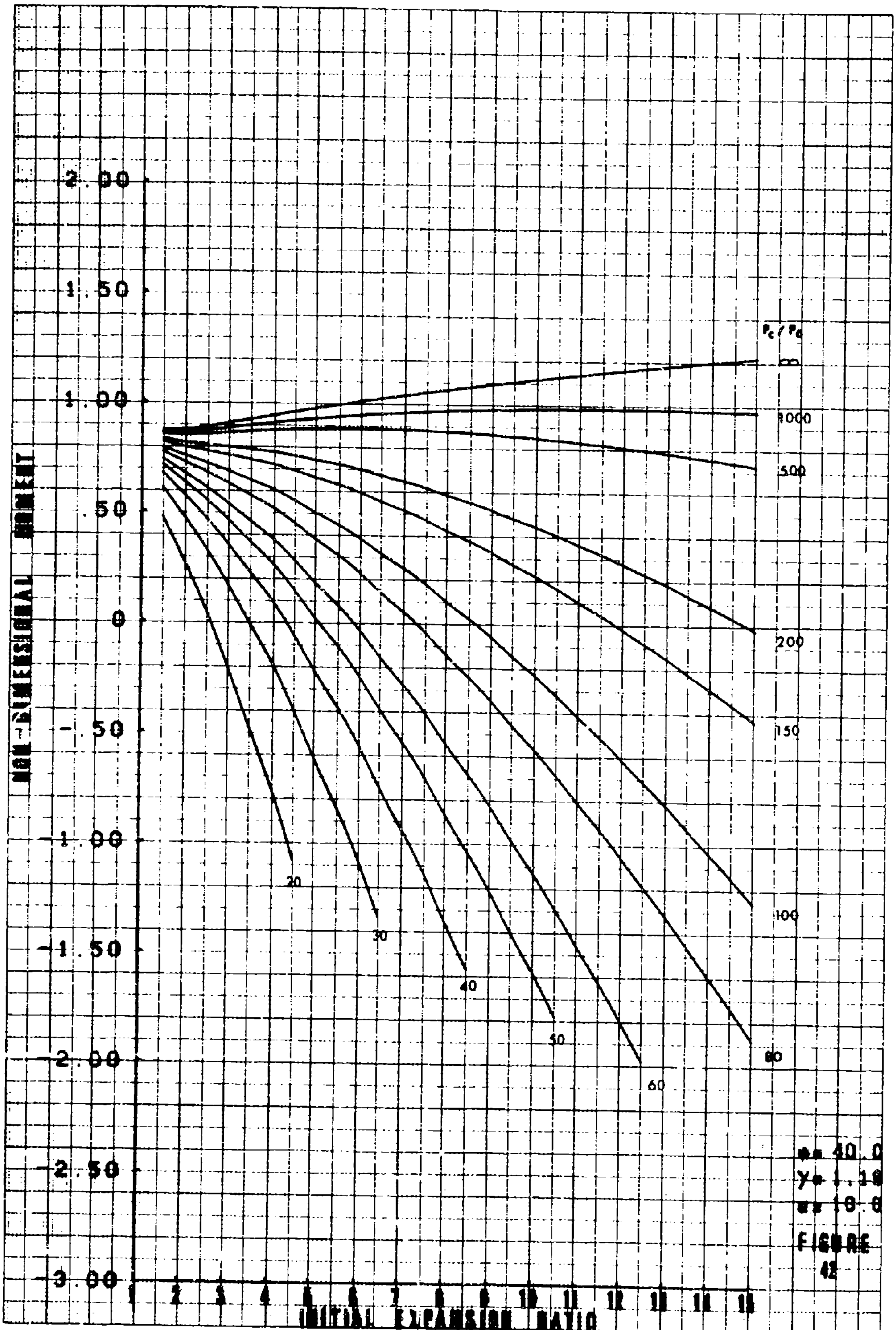
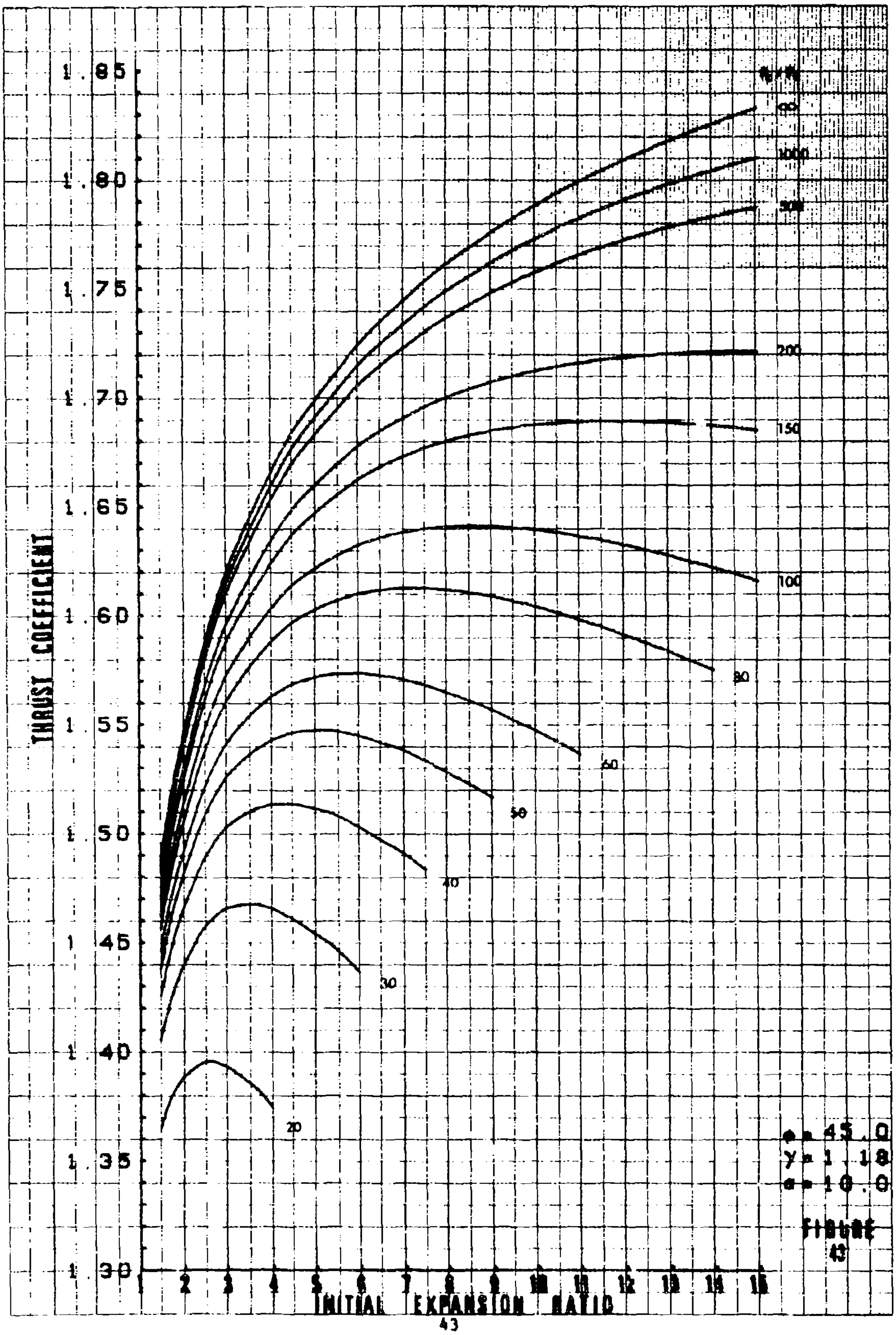
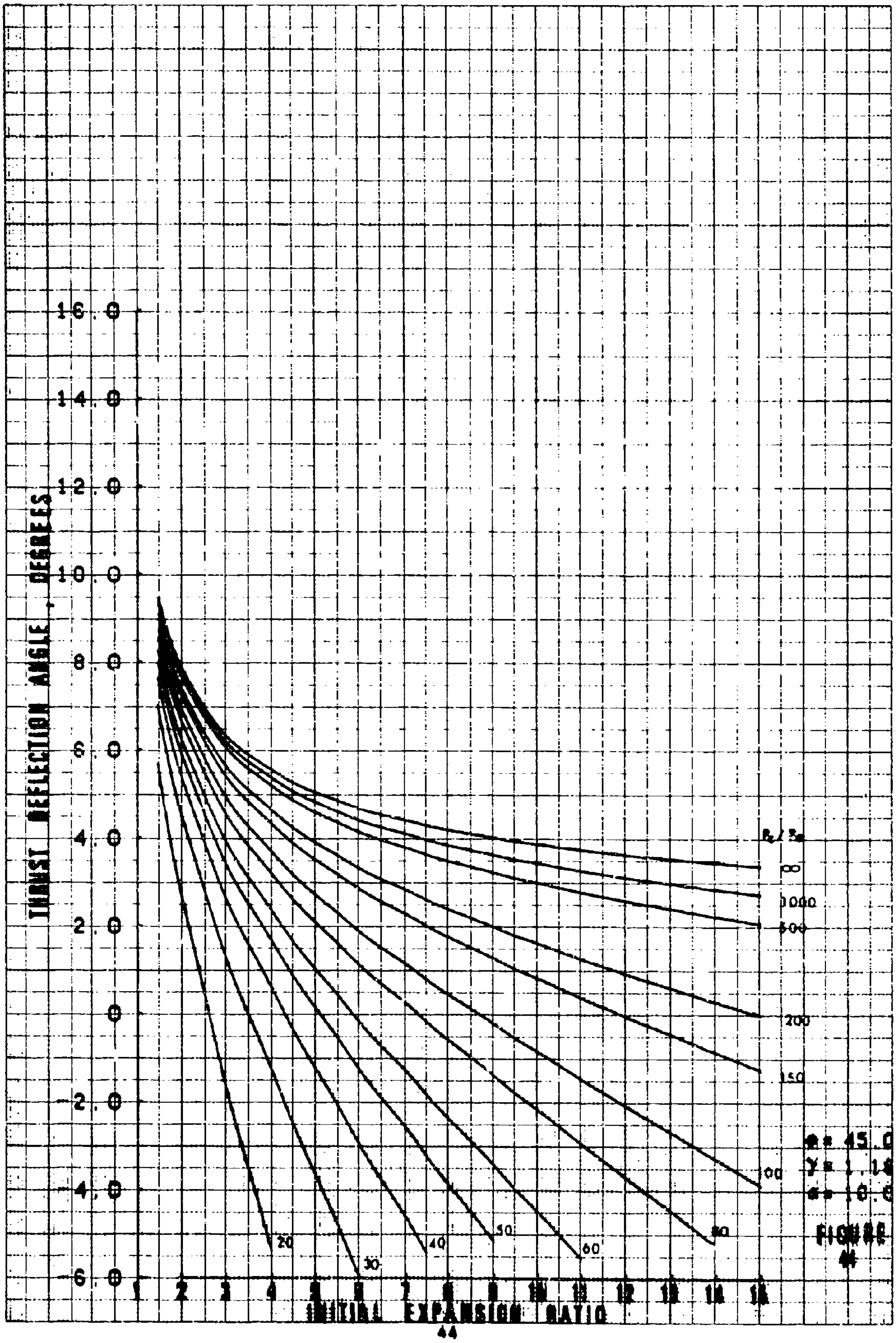
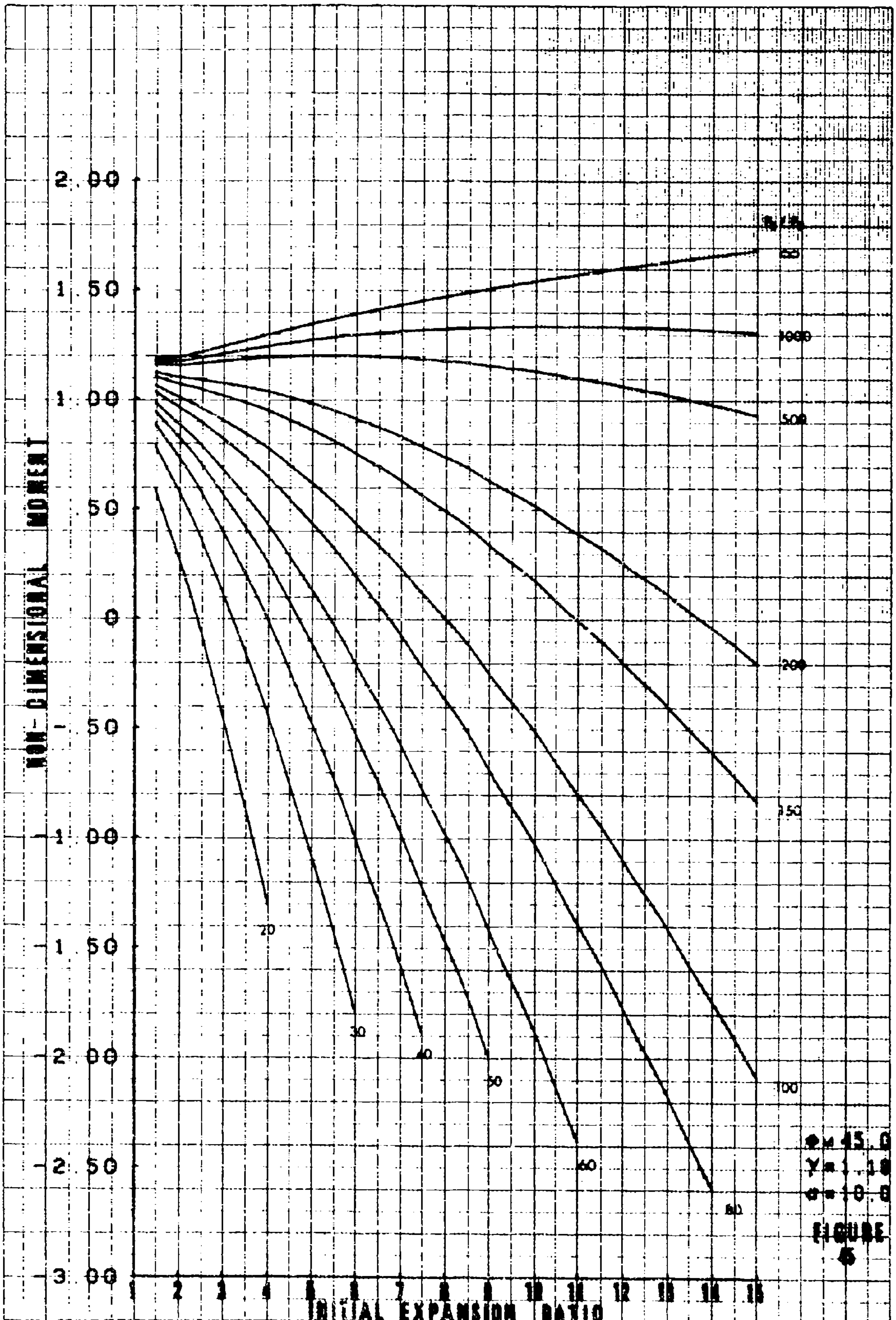

NON-DIMENSIONAL MOMENT
2.00
1.50
1.00
.50
0
-.50
-1.00
-1.50
-2.00
-2.50
-3.00
INITIAL EXPANSION RATIO
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
P_c / P_a
∞
1000
500
200
150
100
80
60
50
40
30
20
40.0

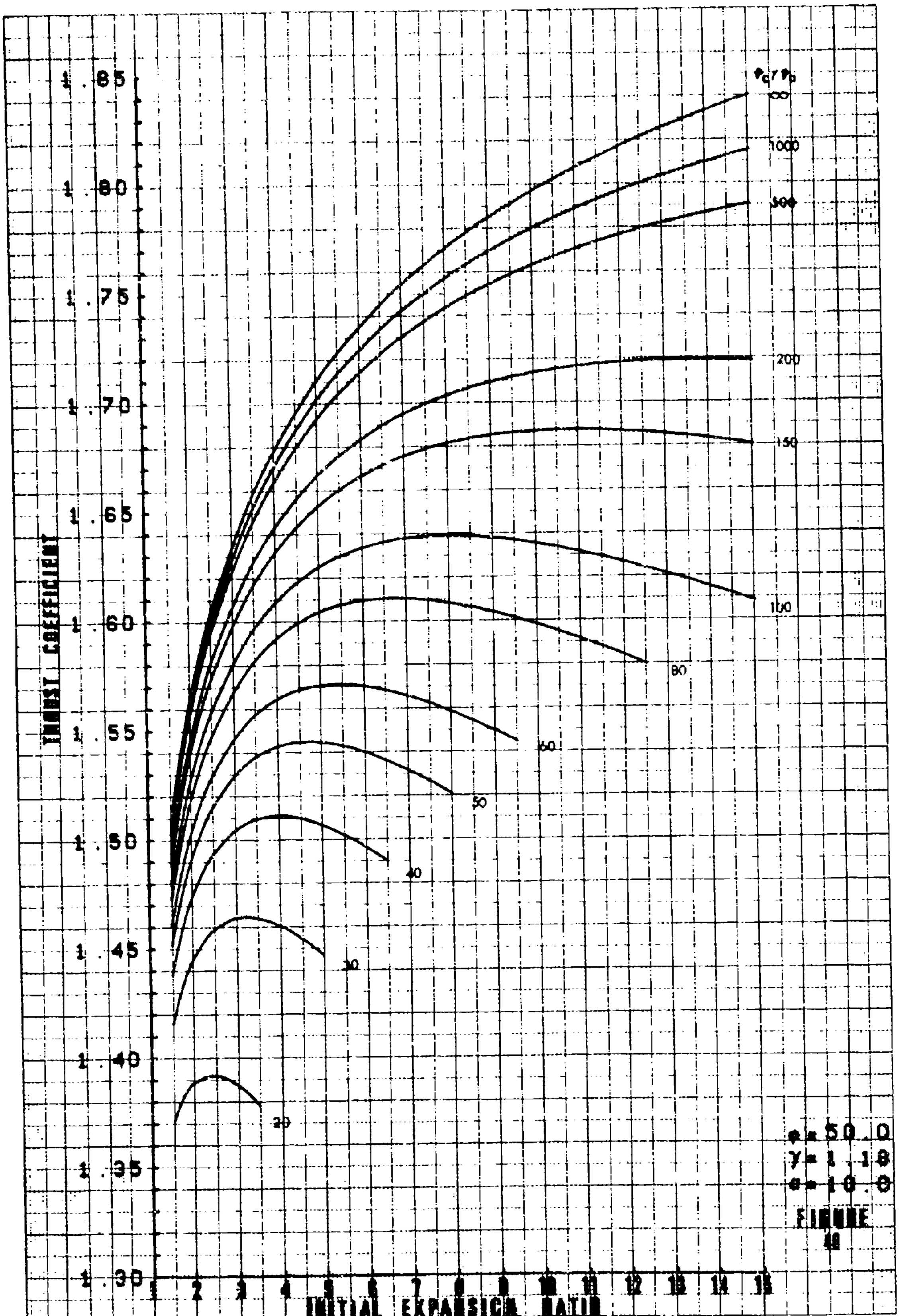
FIGURE 42

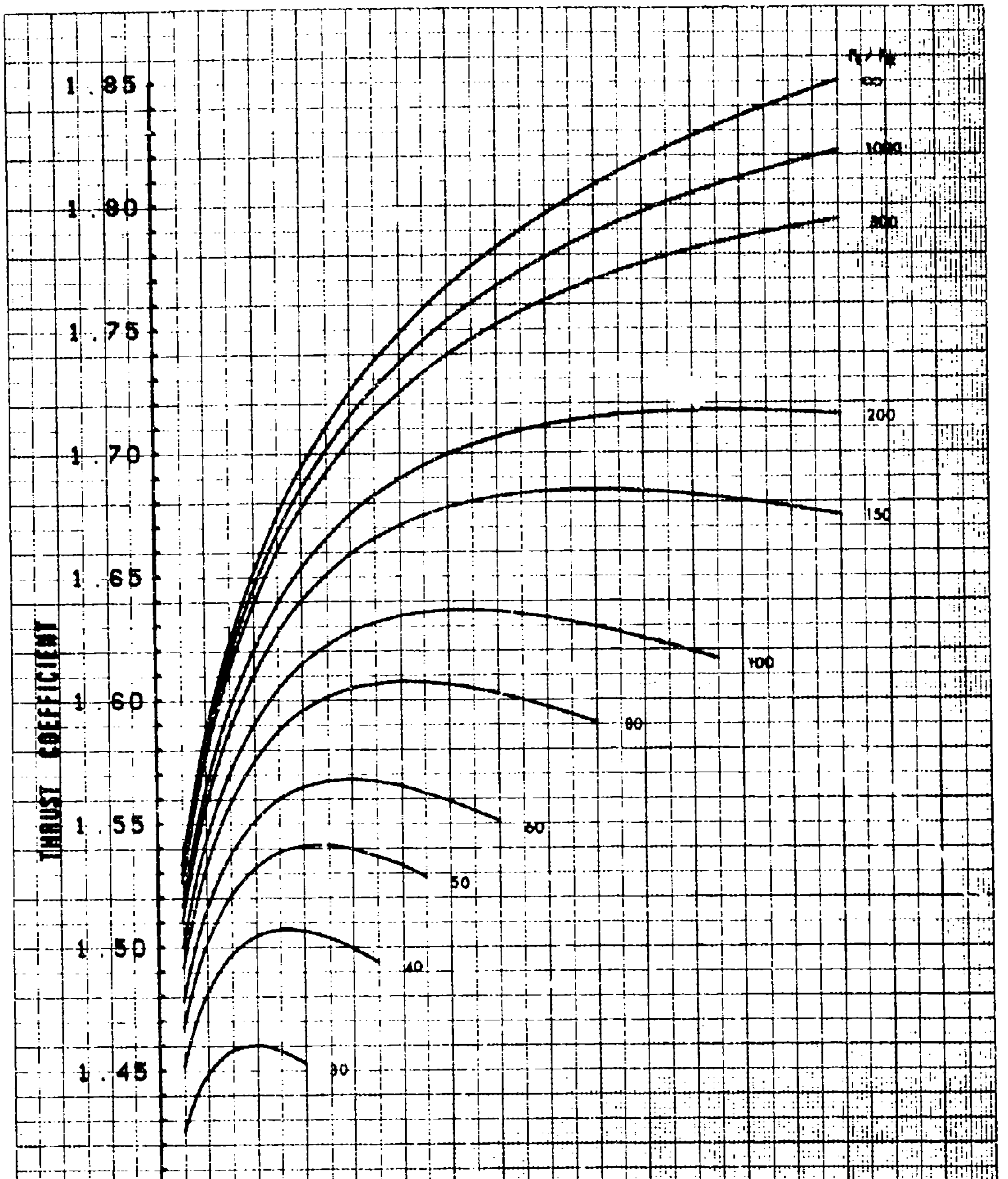


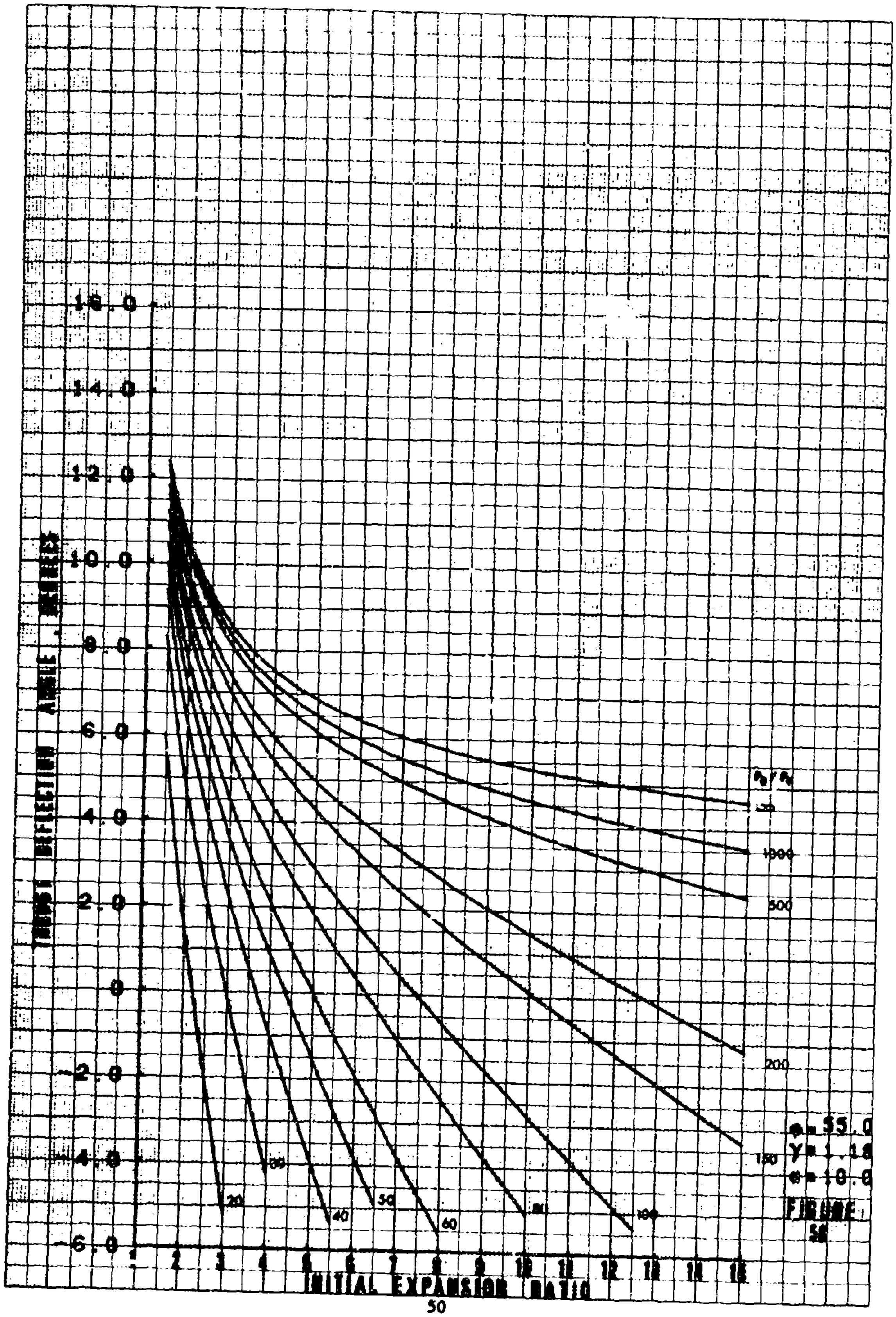
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
THRUST COEFFICIENT
2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
1000
300
200
150
100
80
60
50
40
30
20

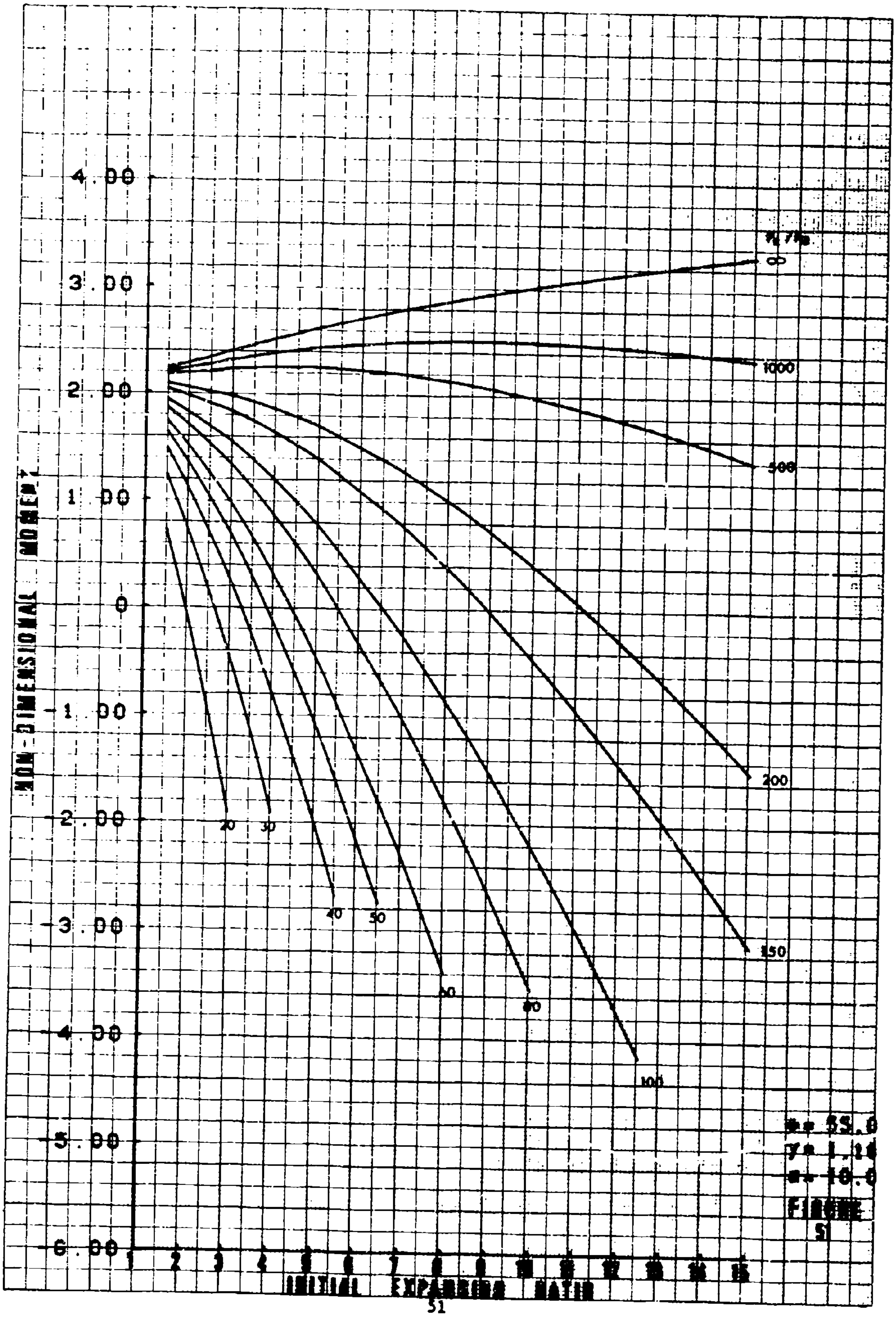

THRUST DEFLECTION ANGLE, DEGREES
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0
-2.0
-4.0
-6.0
INITIAL EXPANSION RATIO
∞
1000
500
200
150
100
80
60
50
40
30
20
FIGURE

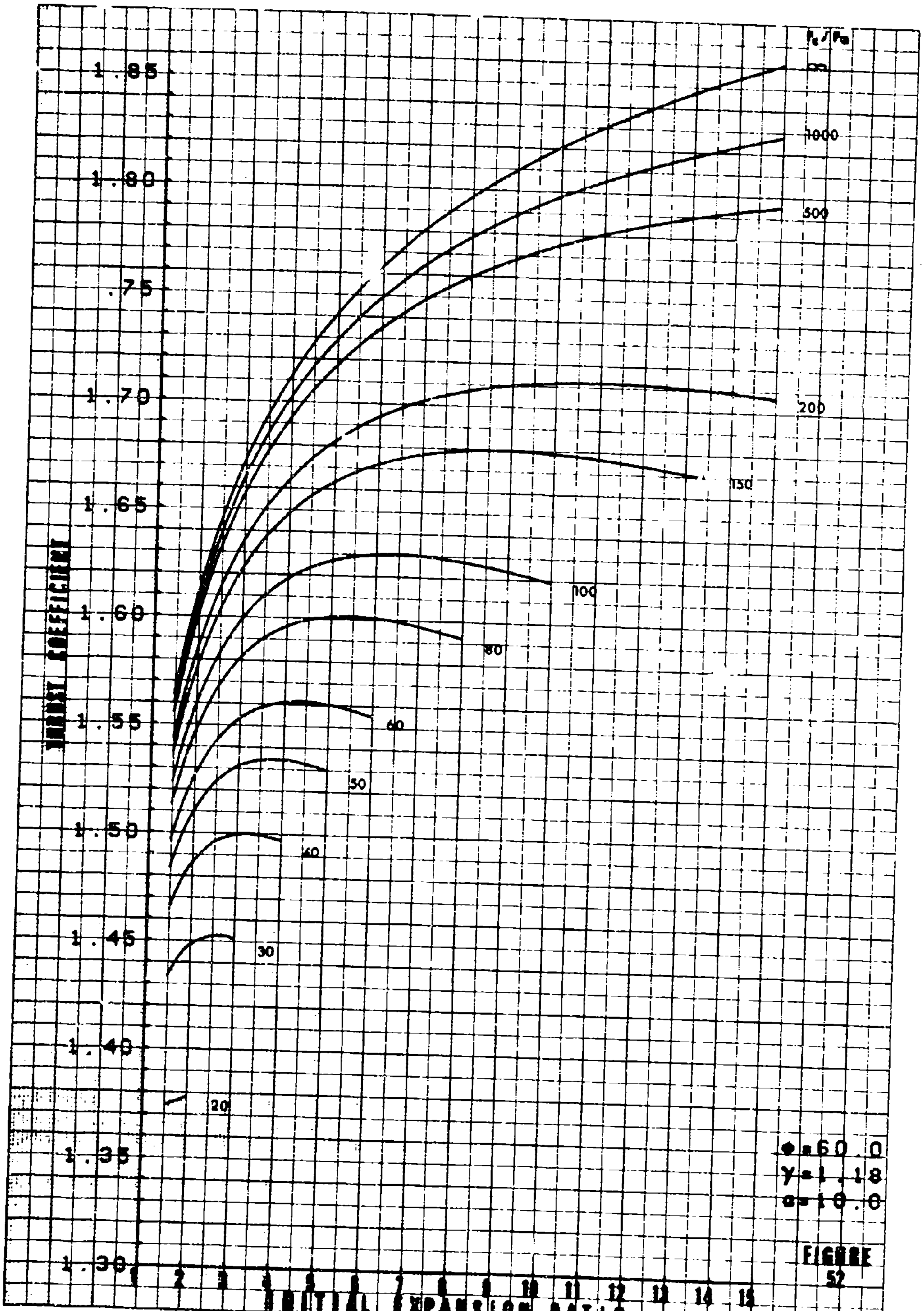

NON-DIMENSIONAL MOMENT
2.00
1.50
1.00
.50
0
-.50
-1.00
-1.50
-2.00
-2.50
-3.00
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
INITIAL EXPANSION RATIO
1000
500
200
150
100
20
30
40
50
60
80


THRUST COEFFICIENT
INITIAL EXPANSION RATIO
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
P_c/P_a
∞
1000
500
200
150
100
80
60
50
40
30
20
γ = 1.18
FIGURE


THRUST COEFFICIENT
INITIAL EXPANSION RATIO
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1000
200
150
100
80
60
50
40
30
20

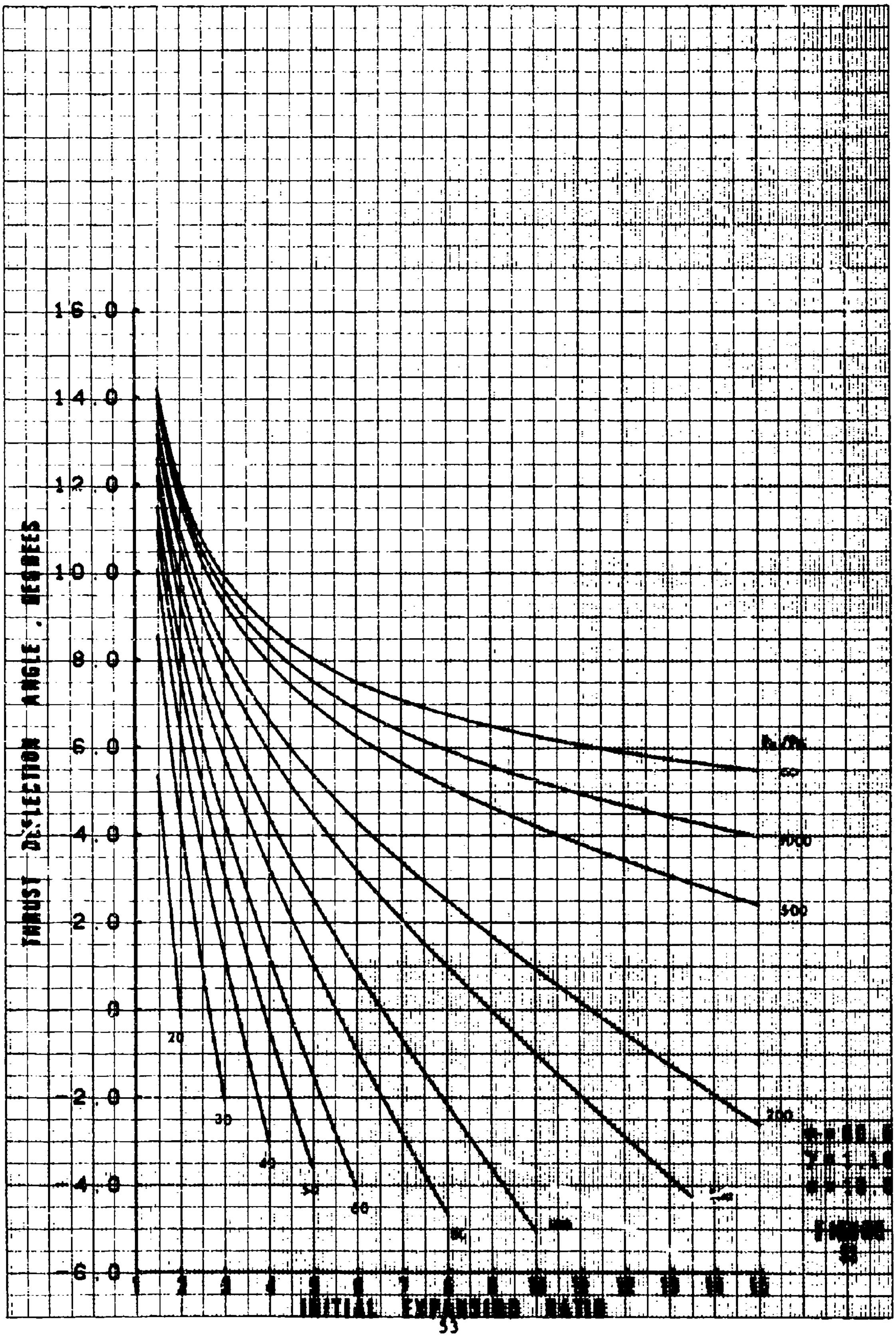

THRUST DEFLECTION ANGLE, DEGREES
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0
-2.0
-4.0
-6.0
INITIAL EXPANSION RATIO
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
20
30
40
50
60
80
100
150
200
500
1000

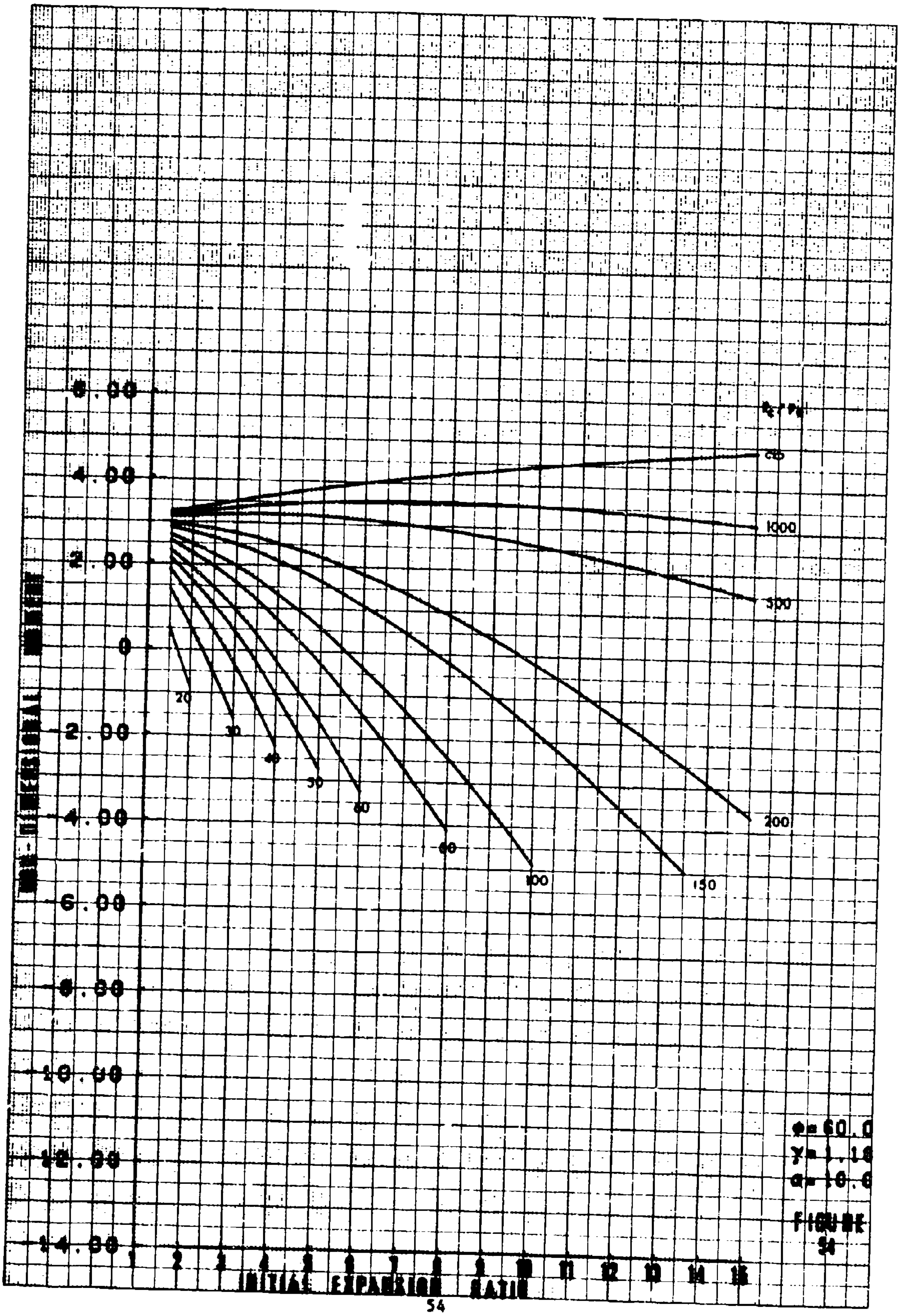

4.00
3.00
2.00
1.00
0
-1.00
-2.00
-3.00
-4.00
-5.00
-6.00
NON-DIMENSIONAL MOMENT
INITIAL EXPANSION RATIO
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
∞
1000
500
200
150
100
80
60
50
40
30
20



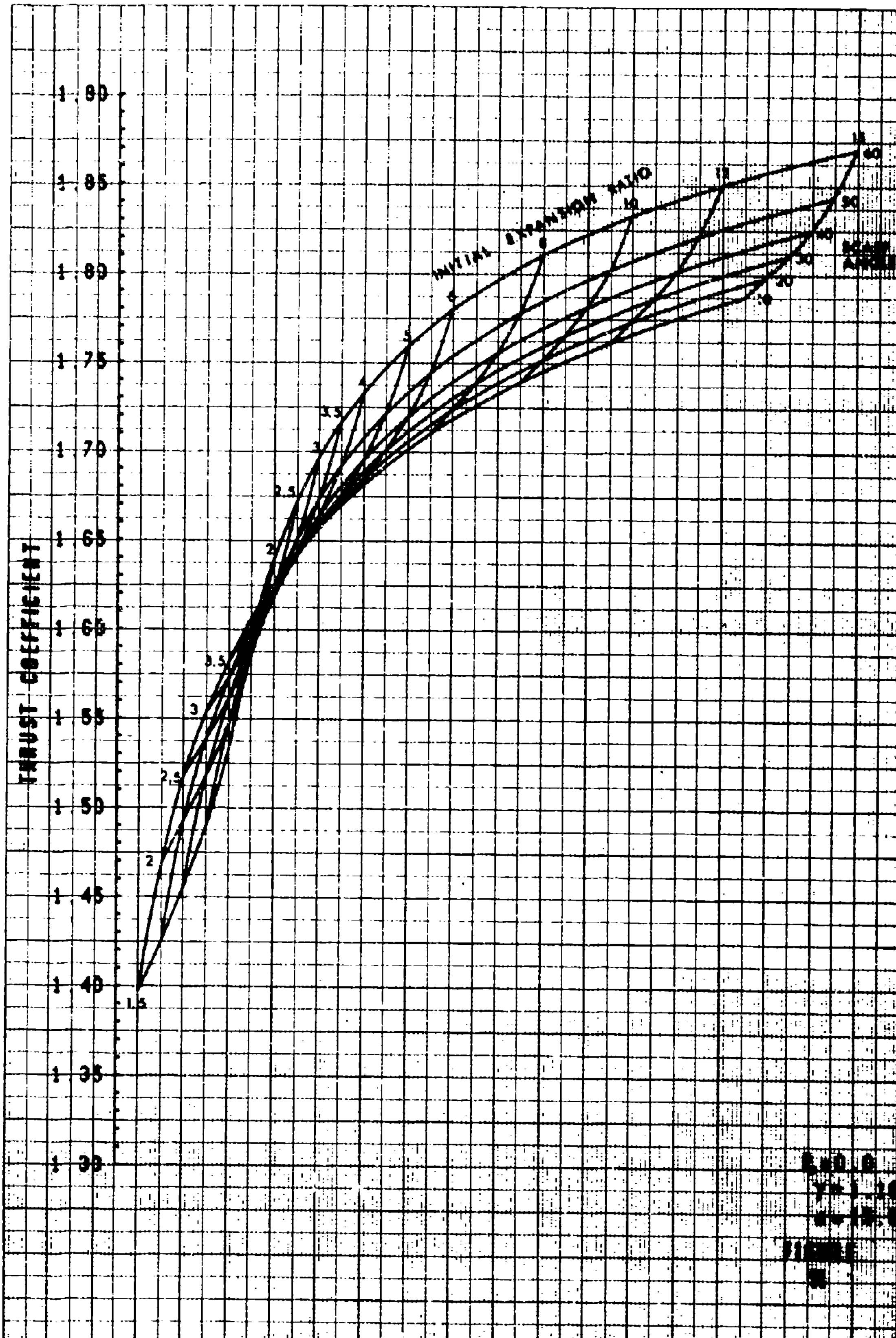
THRUST COEFFICIENT
INITIAL EXPANSION RATIO
Pc/Po
1.85
1.80
.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
∞
1000
500
200
150
100
80
60
50
40
30
20
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
Φ=60.0
γ=1.18
α=10.0

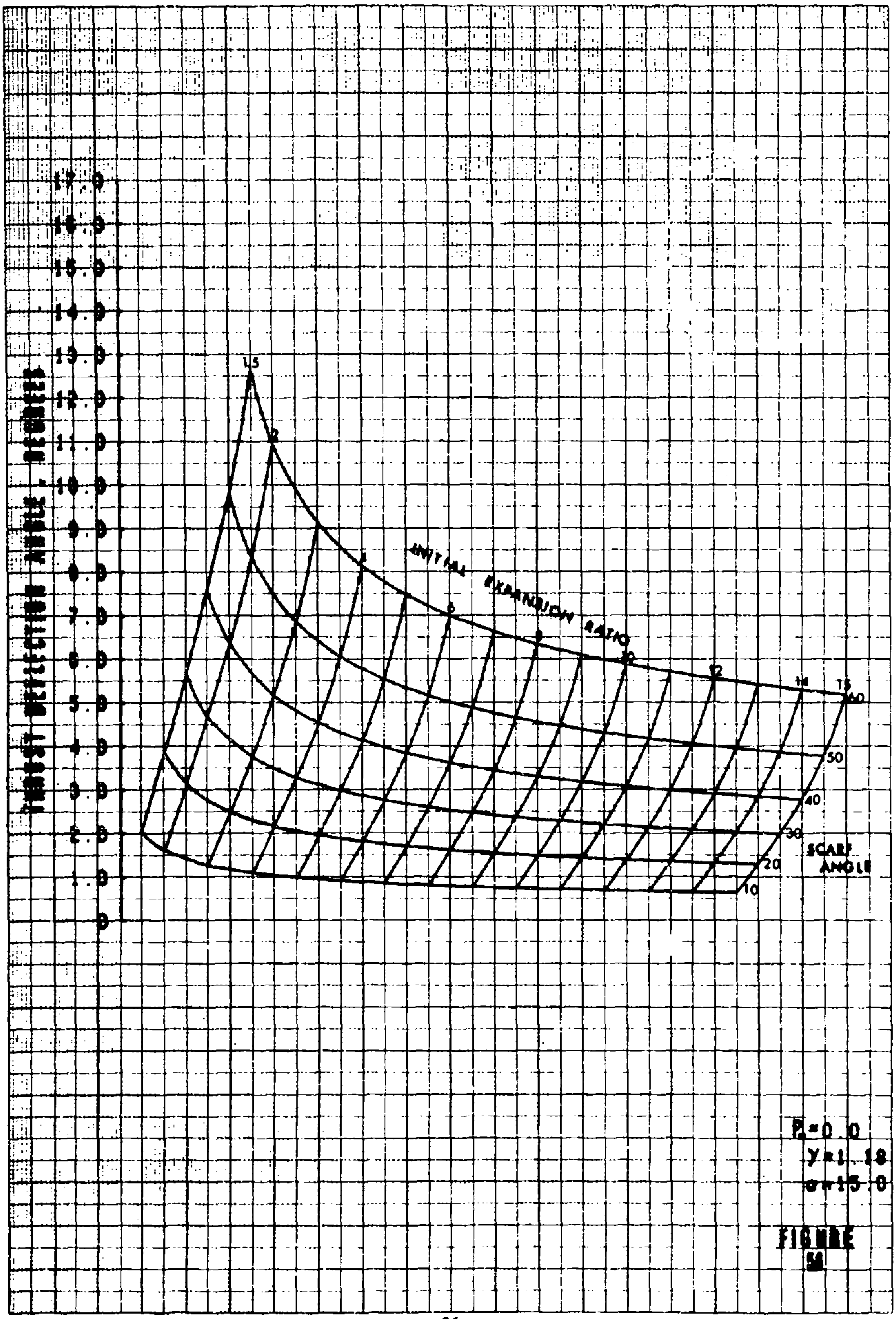
FIGURE 52


16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0
-2.0
-4.0
-6.0
THRUST DEFLECTION ANGLE, DEGREES
INITIAL EXPANSION RATIO
20
30
40
50
60
80
1000
500
200



6.00
4.00
2.00
0
-2.00
-4.00
-6.00
-8.00
-10.00
-12.00
-14.00
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
∞
1000
500
200
150
100
80
60
50
40
30
20
FIGURE


THRUST COEFFICIENT
1.80
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
INITIAL EXPANSION RATIO
1.5
2
2.5
3
3.5
4
5
6
8
10
12
14
10
20
30
40
50
60
BEAM ANGLE


THRUST DEFLECTION ANGLE, DEGREES
INITIAL EXPANSION RATIO
SCARF ANGLE
10
20
30
40
50
60

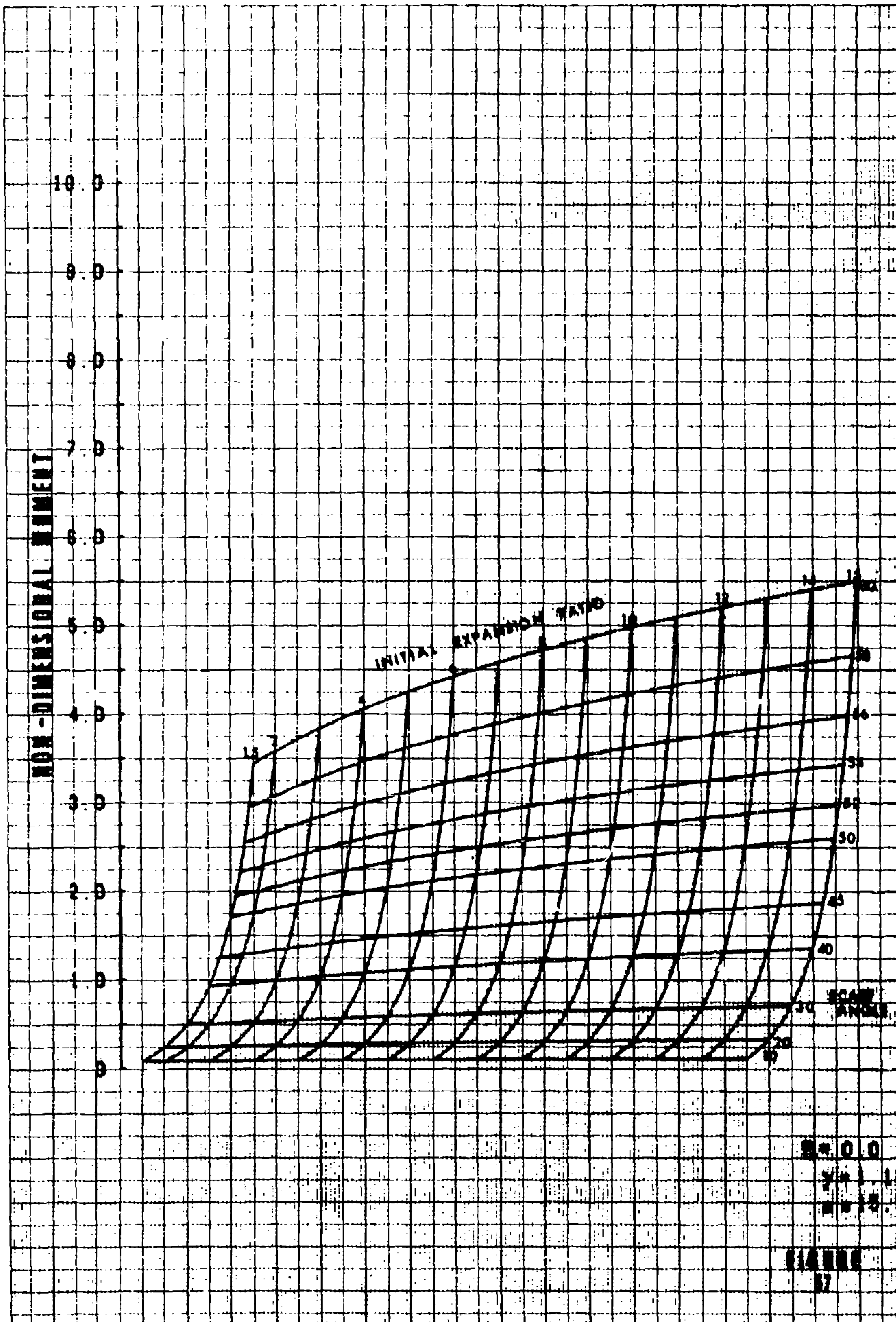
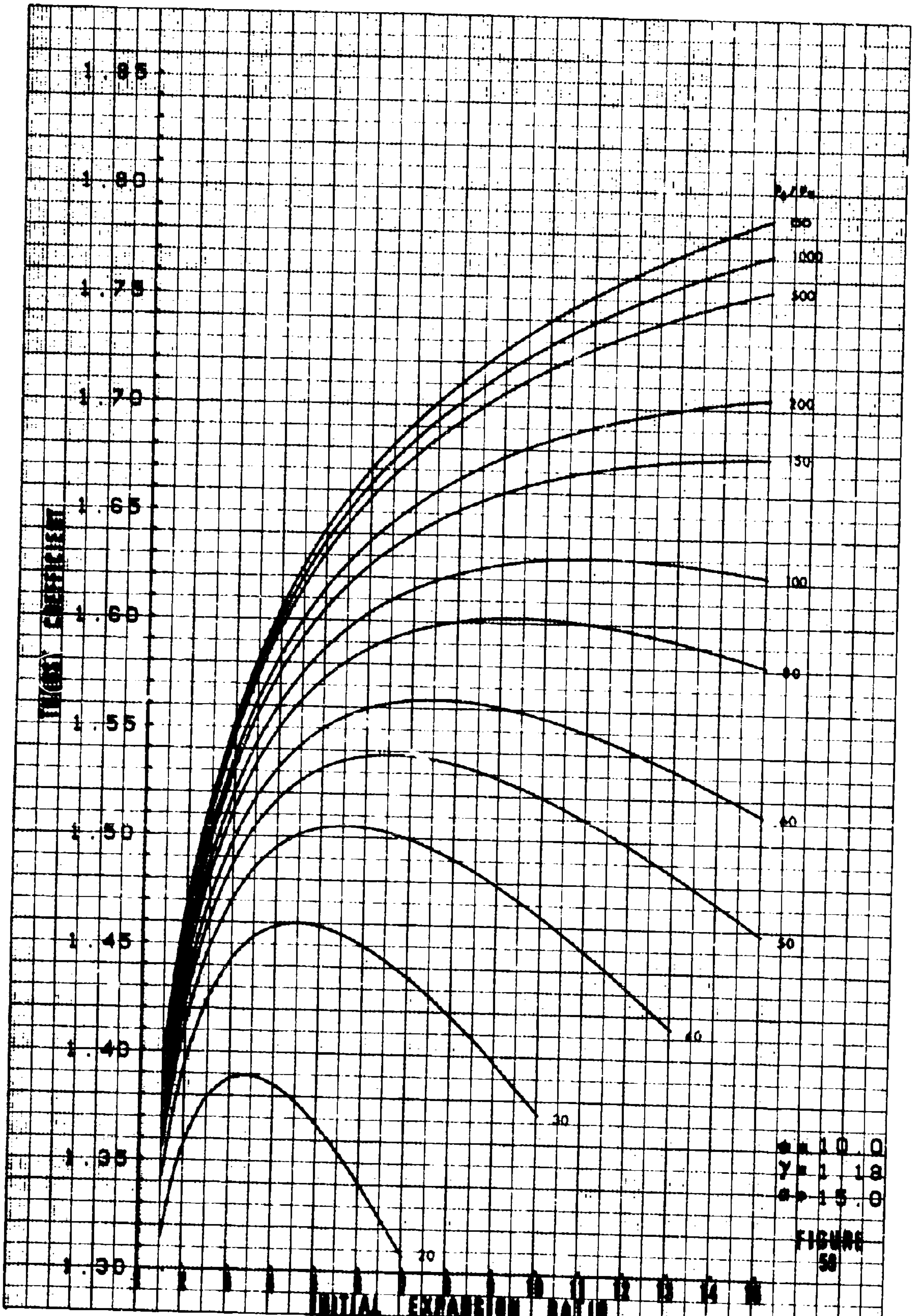
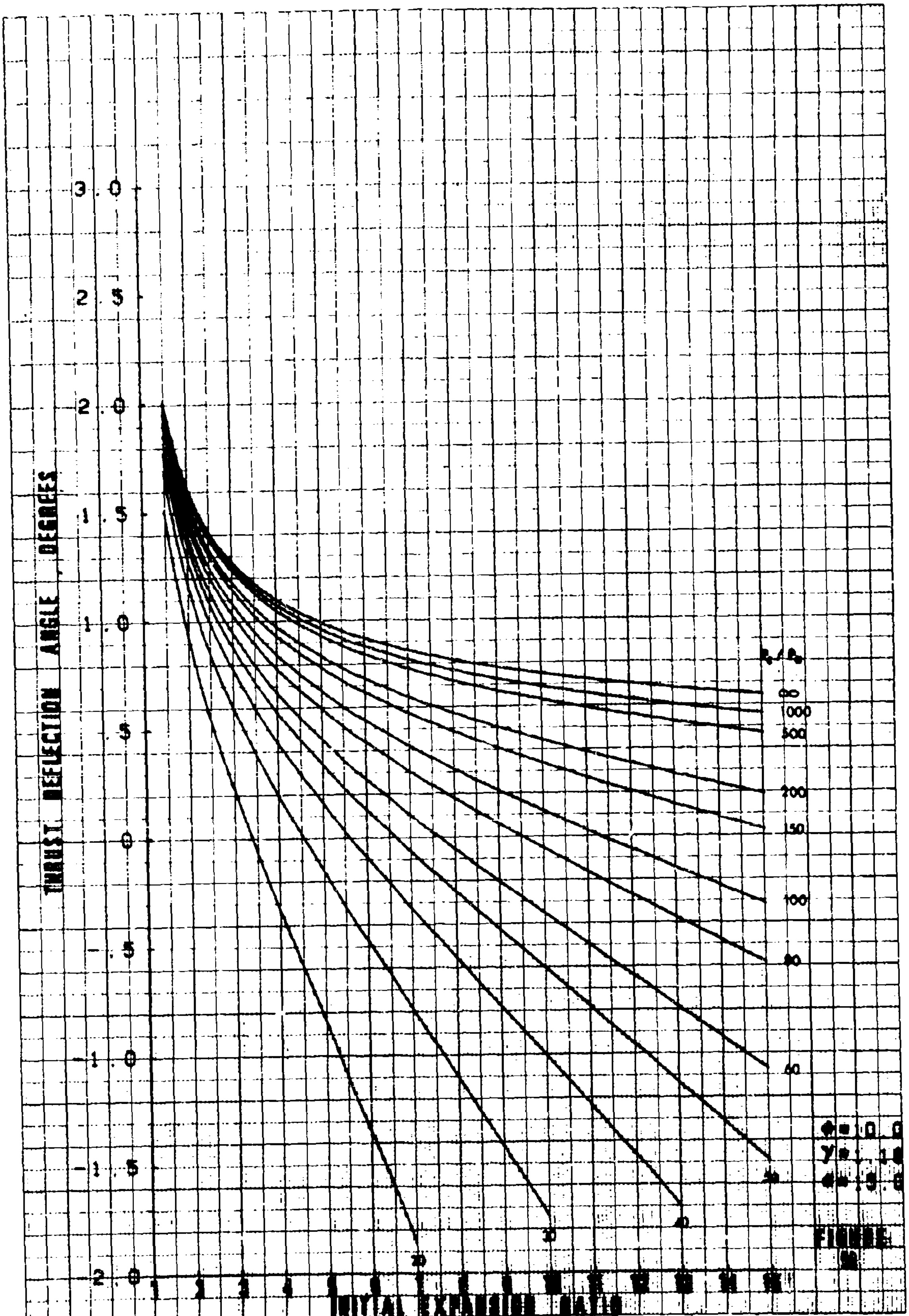

NON-DIMENSIONAL MOMENT
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
INITIAL EXPANSION RATIO
1.5
2
4
6
8
10
12
14
50
45
40
20

FIGURE
57

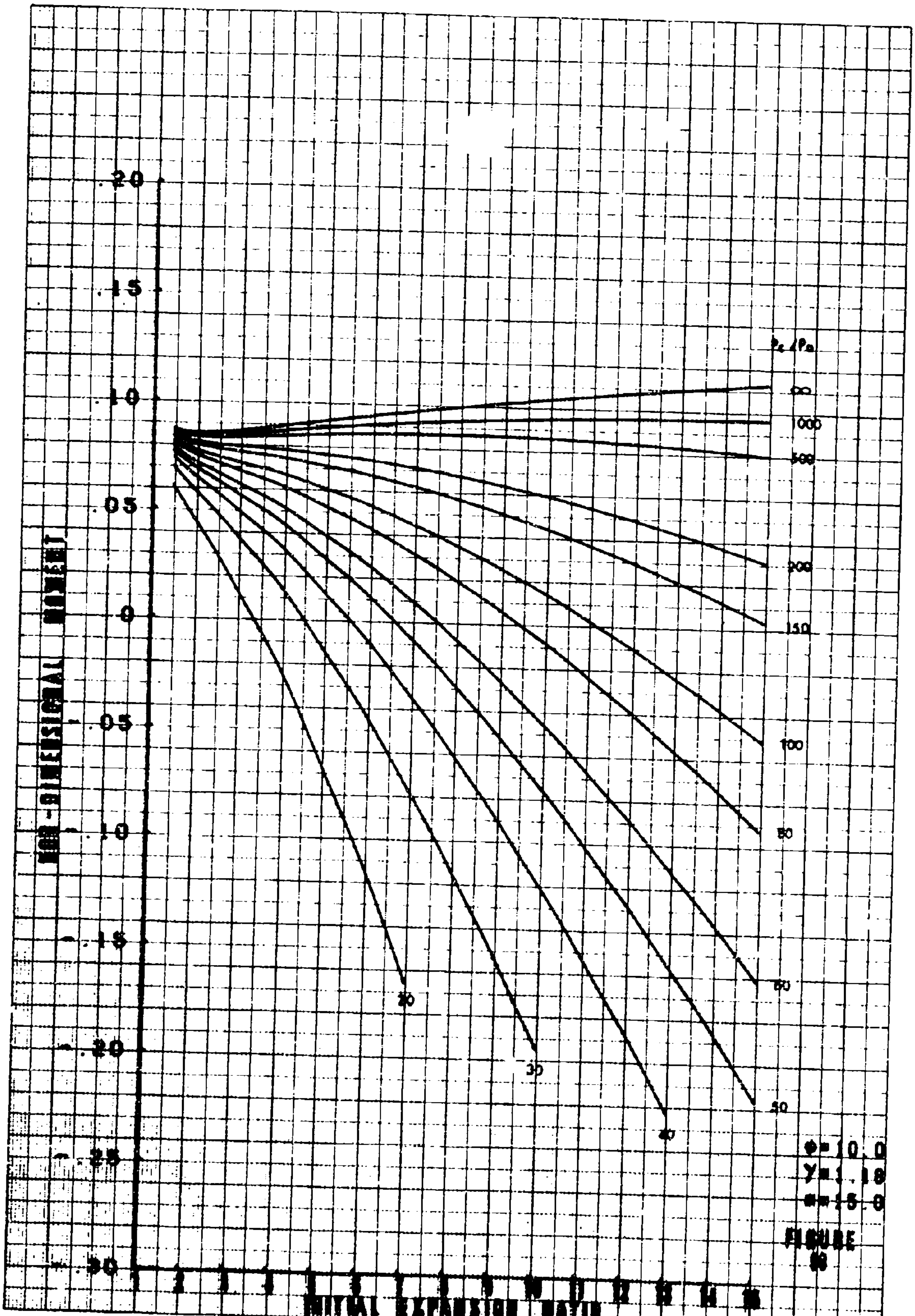


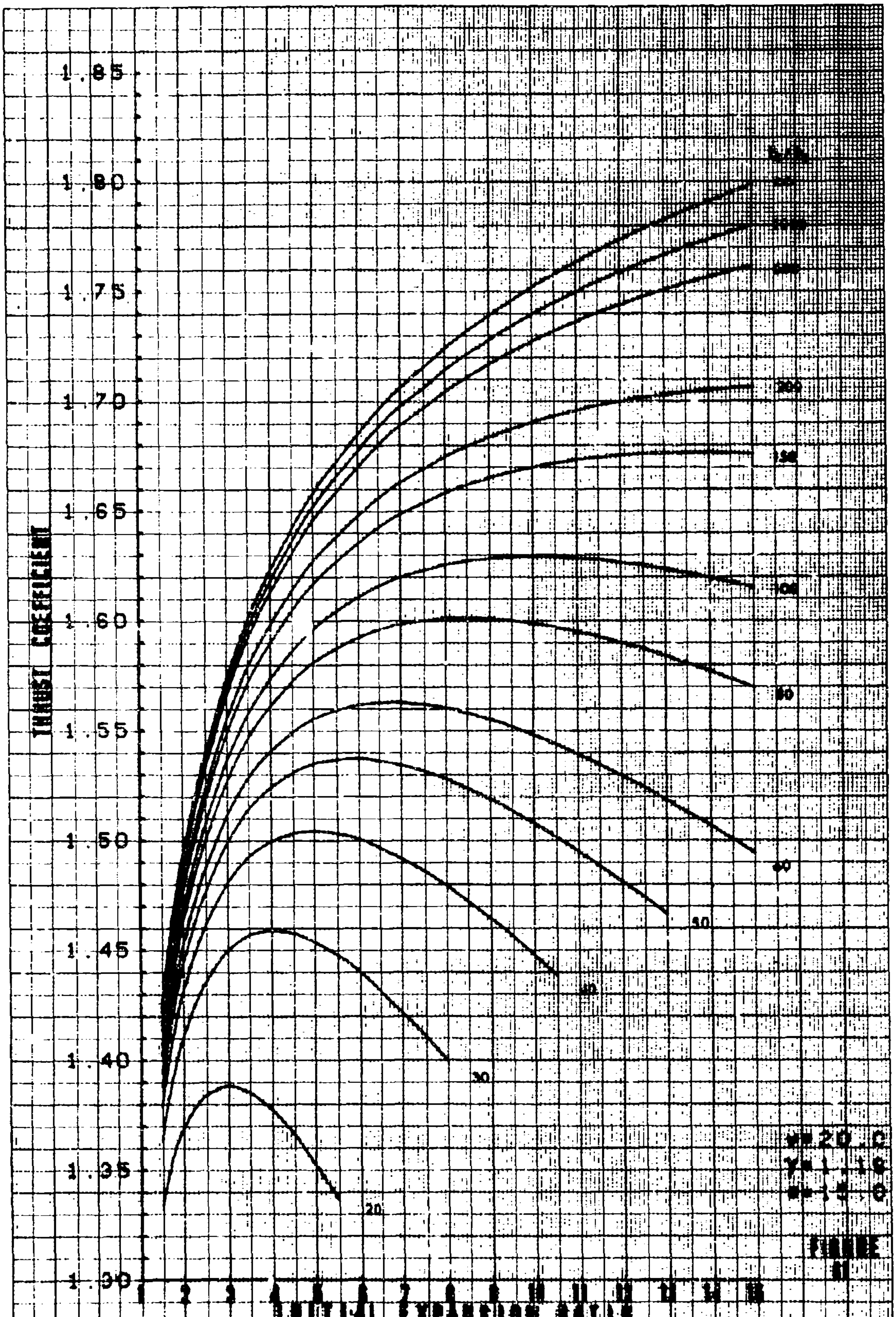
THRUST COEFFICIENT
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
INITIAL EXPANSION RATIO
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
P_c/P_a
1500
1000
500
200
150
100
80
60
50
40
30
20

FIGURE 58

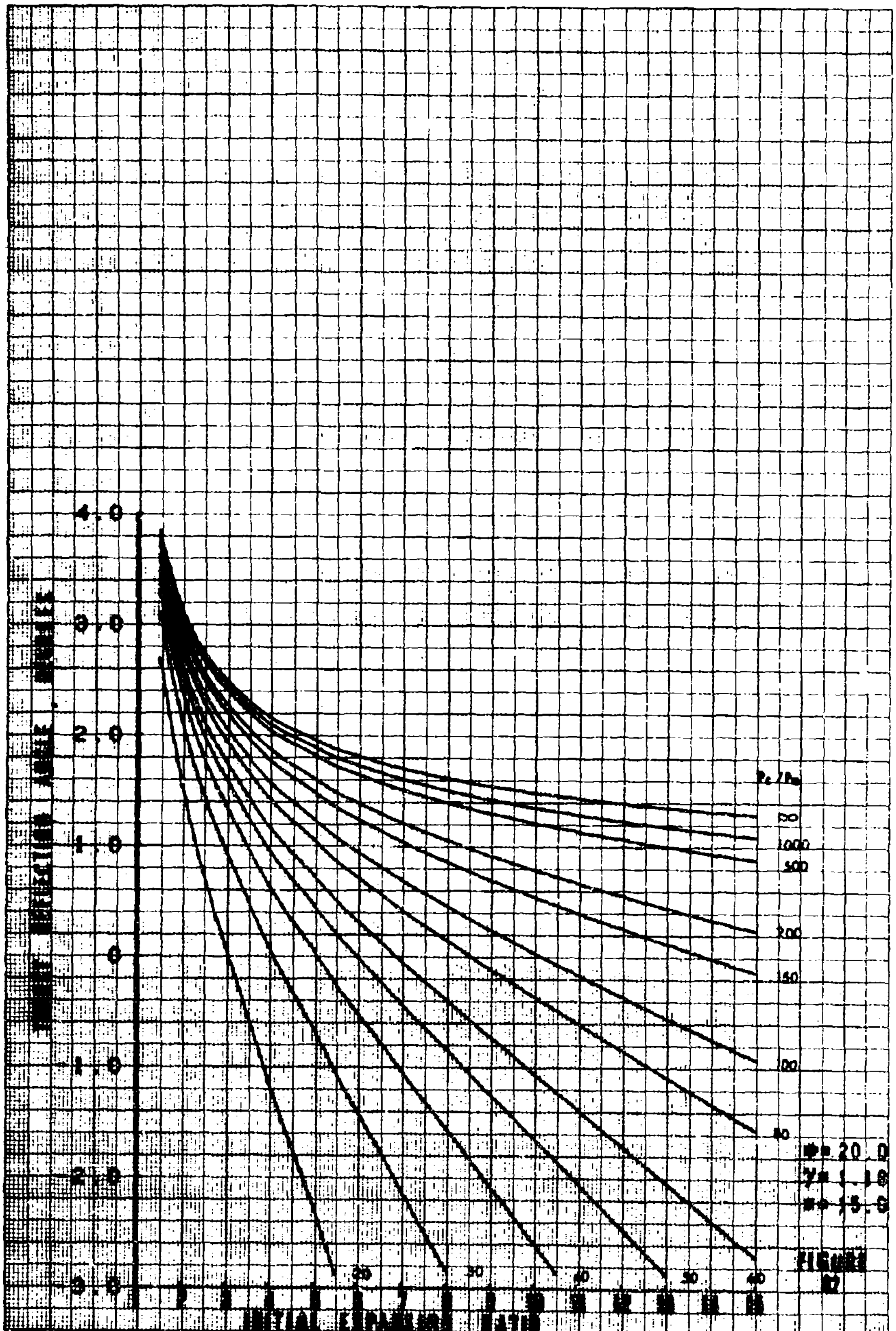


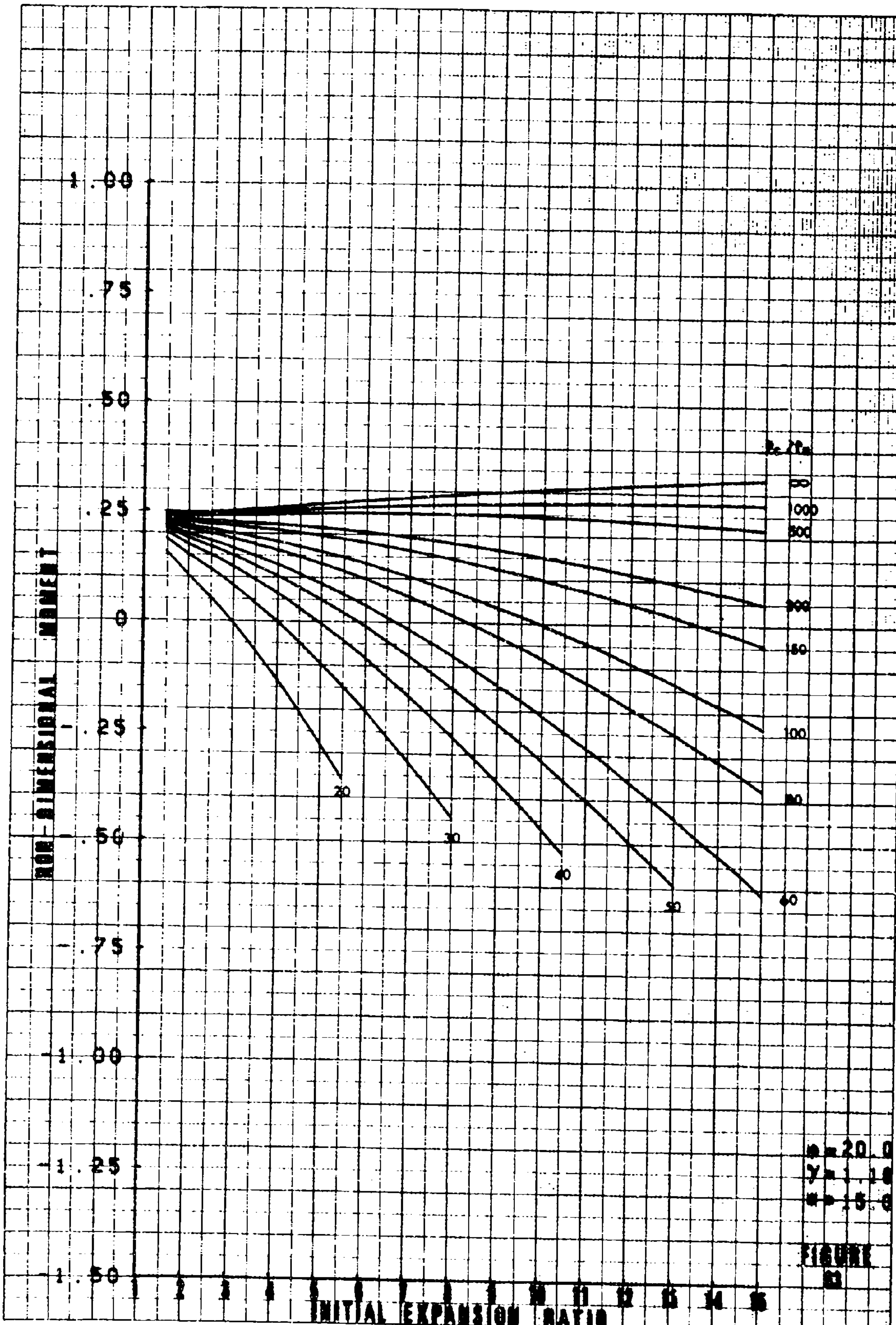
THRUST DEFLECTION ANGLE, DEGREES
3.0
2.5
2.0
1.5
1.0
.5
0
-.5
-1.0
-1.5
-2.0
INITIAL EXPANSION RATIO
∞
1000
500
200
150
100
80
60
50
40
30
20
FIGURE


.20
.15
.10
.05
0
-.05
-.10
-.15
-.20
-.25
-.30
NON-DIMENSIONAL MOMENT
INITIAL EXPANSION RATIO
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
P_c/P_a
∞
1000
500
200
150
100
80
60
50
40
30
20
FIGURE

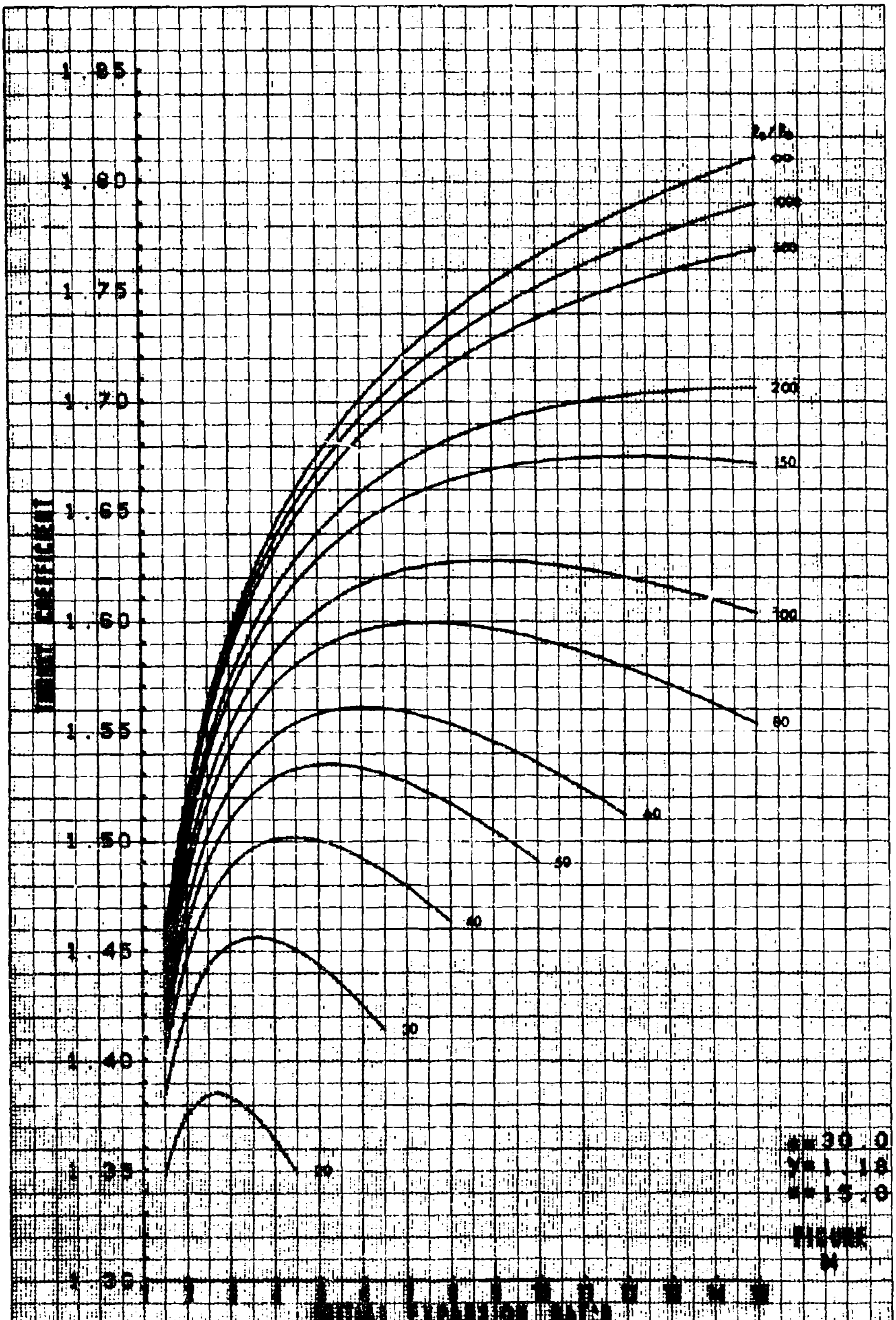


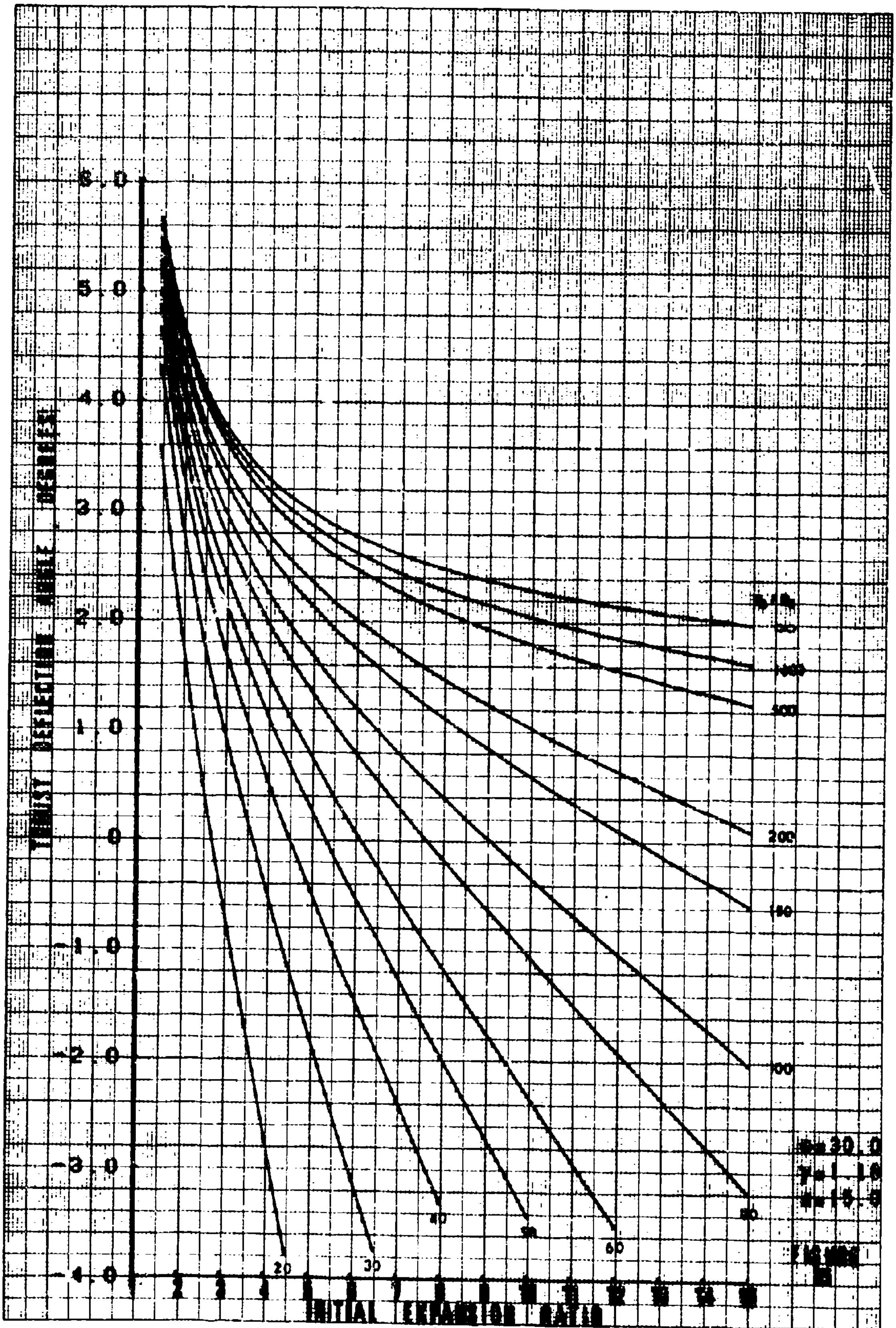
THRUST COEFFICIENT
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
INITIAL EXPANSION RATIO
200
150
100
80
60
50
40
30
20
FIGURE


4.0
3.0
2.0
1.0
0
Pc/Pa
∞
1000
500
200
150
100
80
20
30
40
50
40
INITIAL EXPANSION RATIO

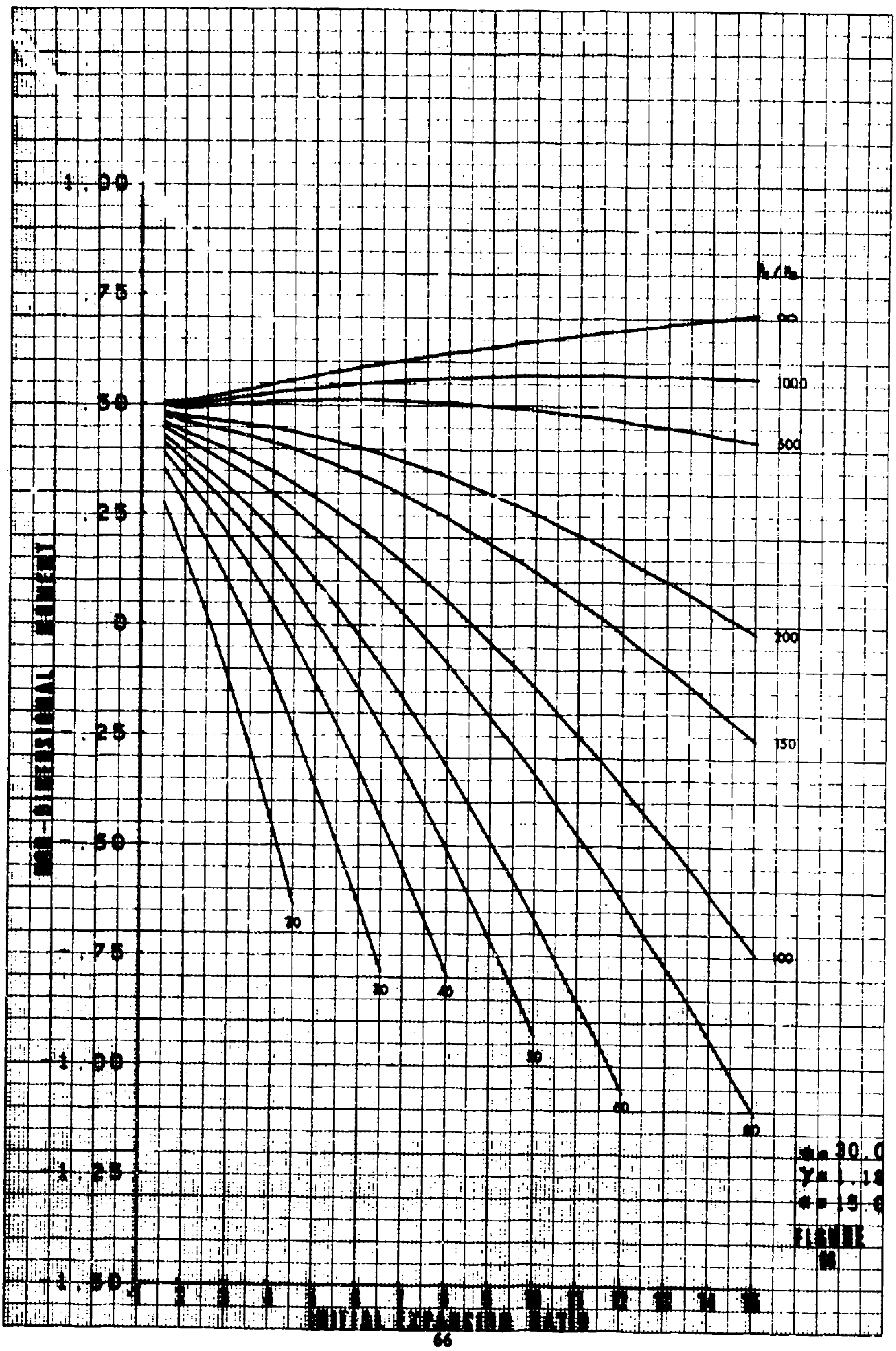


NON-DIMENSIONAL MOMENT
INITIAL EXPANSION RATIO
1.00
.75
.50
.25
0
-.25
-.50
-.75
-1.00
-1.25
-1.50
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
20
30
40
50
60
100
150
300
500
1000
FIGURE

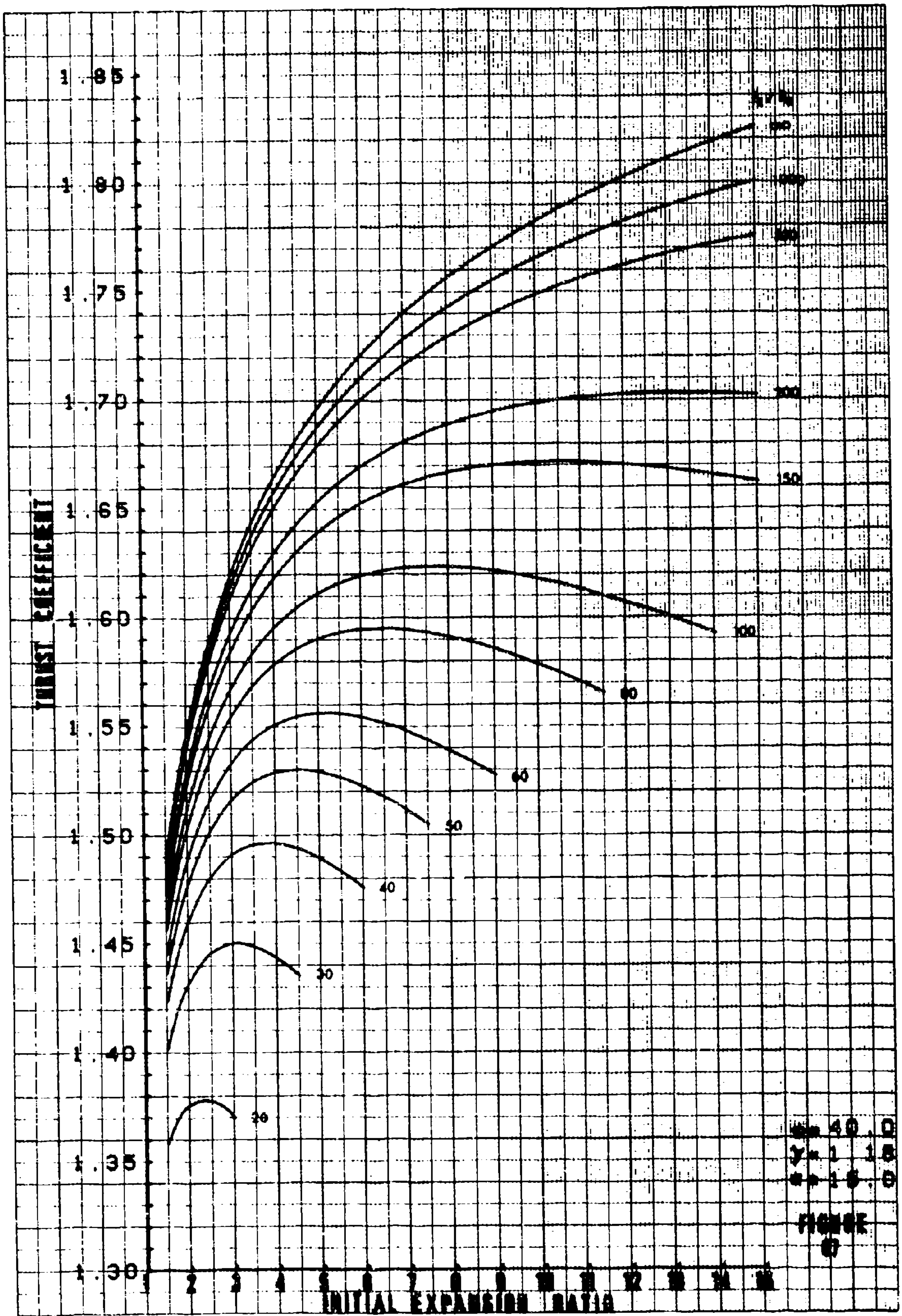

1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1000
500
200
150
100
80
40
30
20



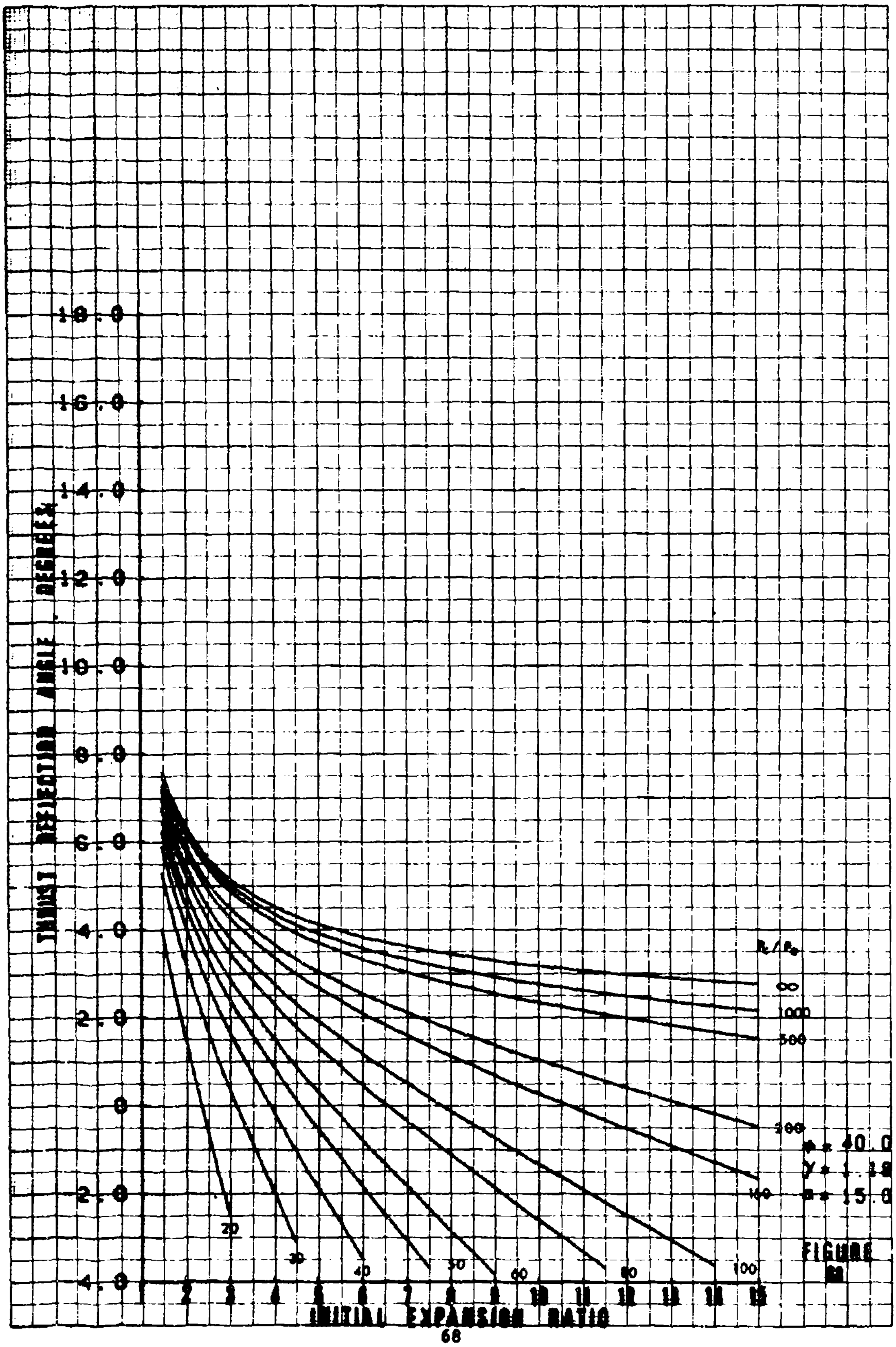
5.0
4.0
3.0
2.0
1.0
0
-1.0
-2.0
-3.0
-4.0
1000
500
200
150
100
80
60
40
30
20
INITIAL EXPANSION RATIO



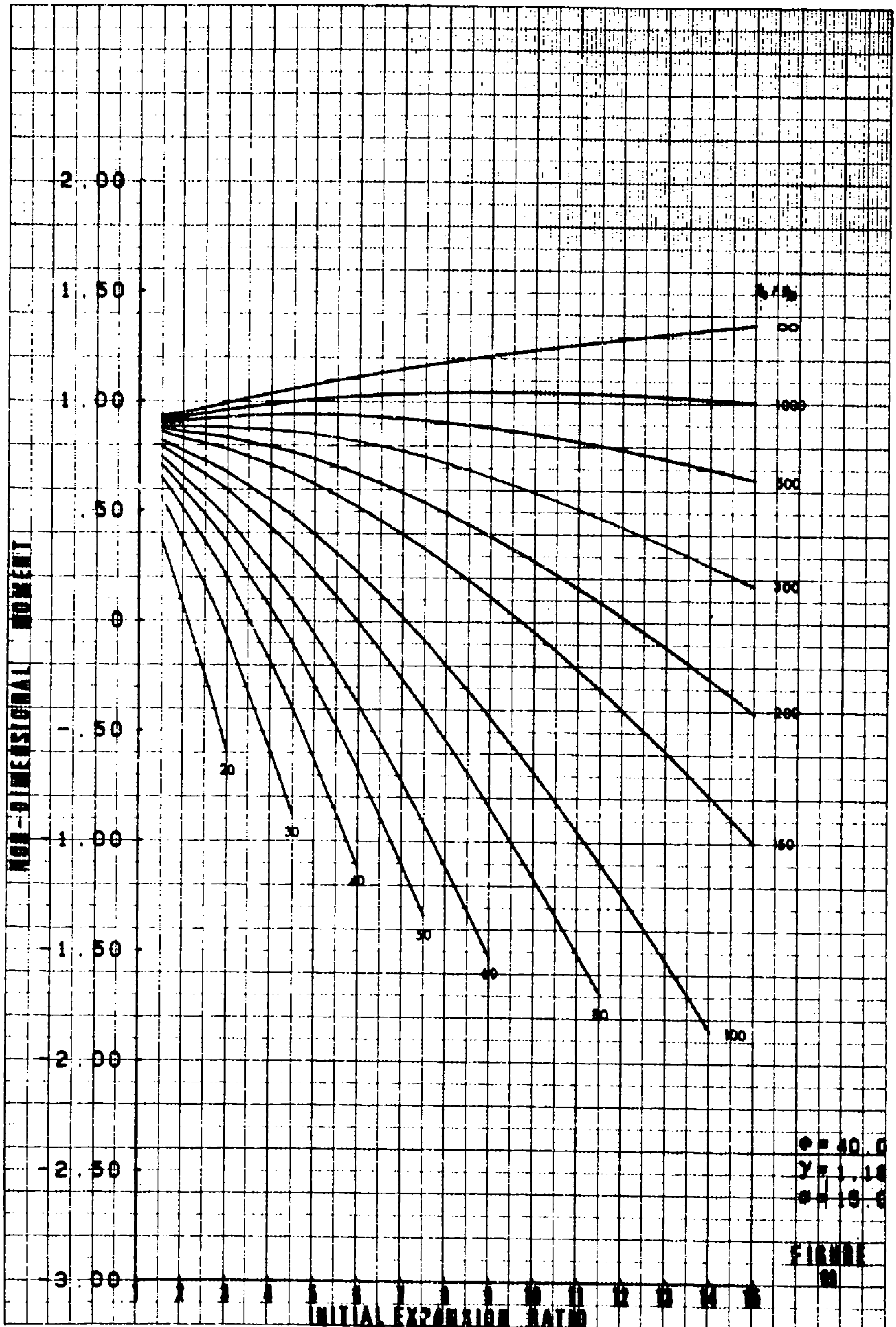
1.00
.75
.50
.25
0
-.25
-.50
-.75
-1.00
-1.25
-1.50
1000
500
200
150
100
80
70
60
50
40
30
20
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
FIGURE



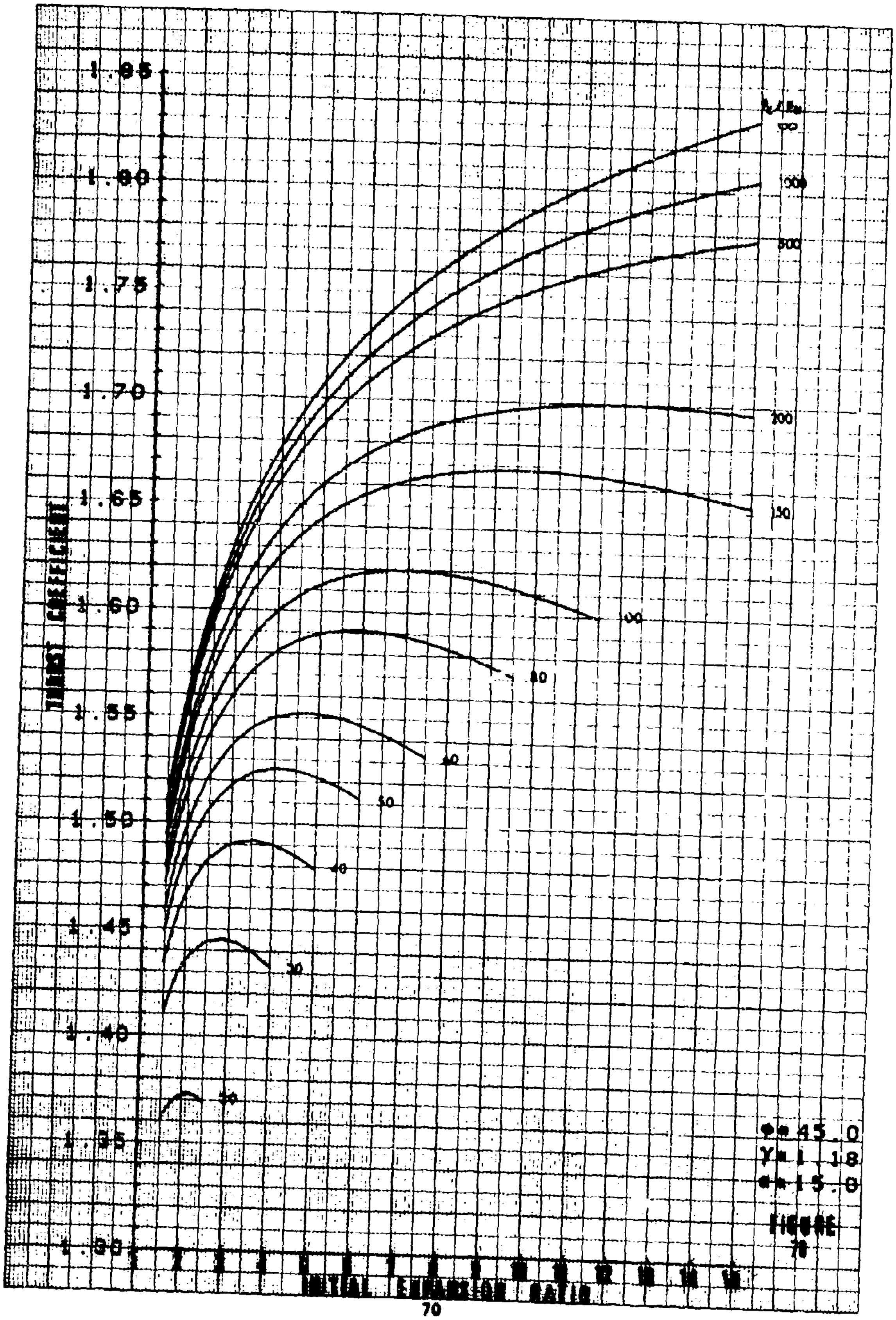
THRUST COEFFICIENT
INITIAL EXPANSION RATIO
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
20
30
40
50
60
80
100
150
200
FIGURE



THRUST DEFLECTION ANGLE, DEGREES
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0
-2.0
-4.0
INITIAL EXPANSION RATIO
P_c/P_e
∞
1000
500
200
100
20
30
40
50
60
80
100
FIGURE



2.00
1.50
1.00
.50
0
-.50
-1.00
-1.50
-2.00
-2.50
-3.00
NON-DIMENSIONAL MOMENT
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
∞
1000
500
300
200
150
100
80
60
50
40
30
20



THRUST COEFFICIENT
INITIAL EXPANSION RATIO
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
∞
1000
500
200
150
100
80
60
50
40
30
Φ= 45.0
γ= 1.18
α= 15.0
FIGURE

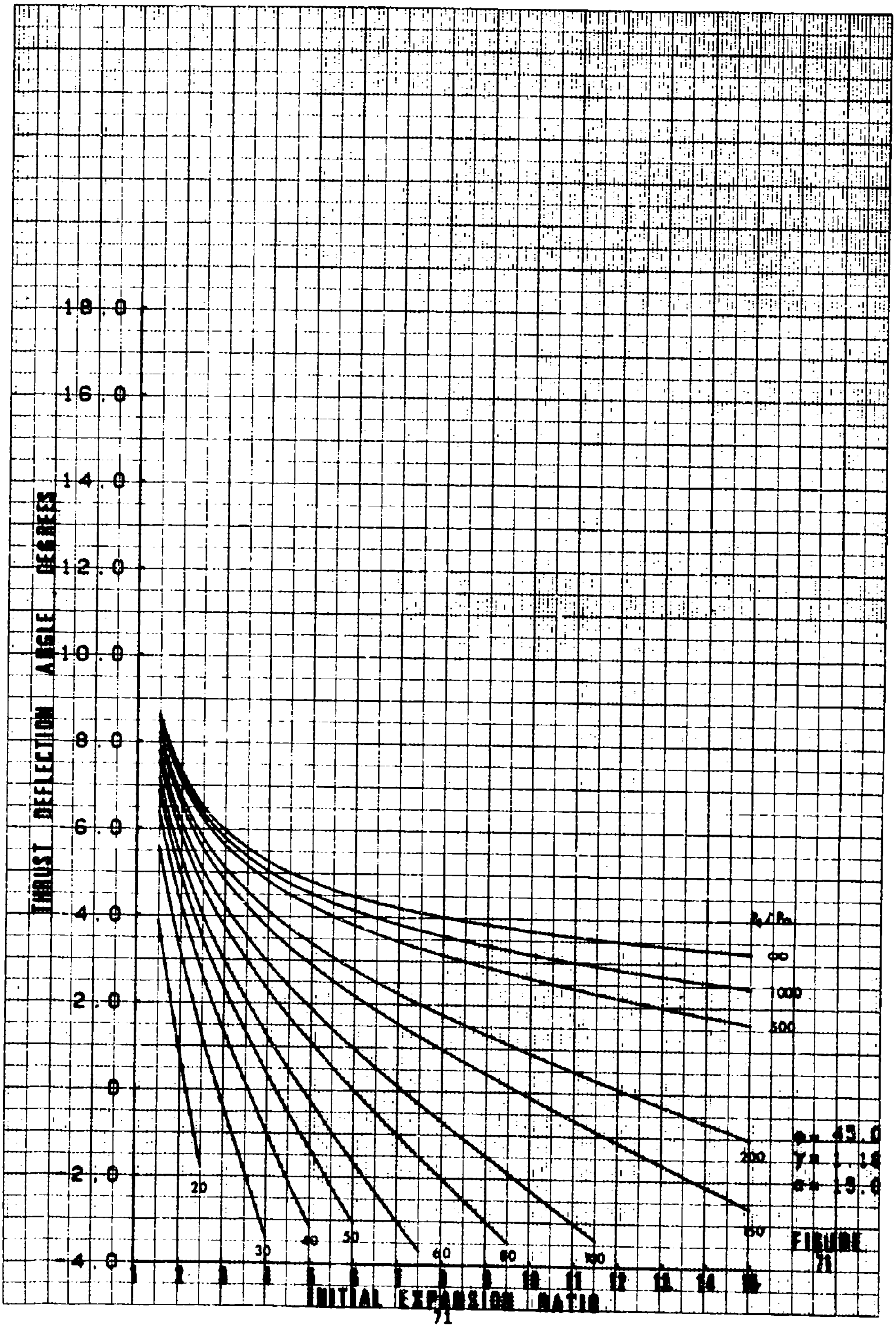
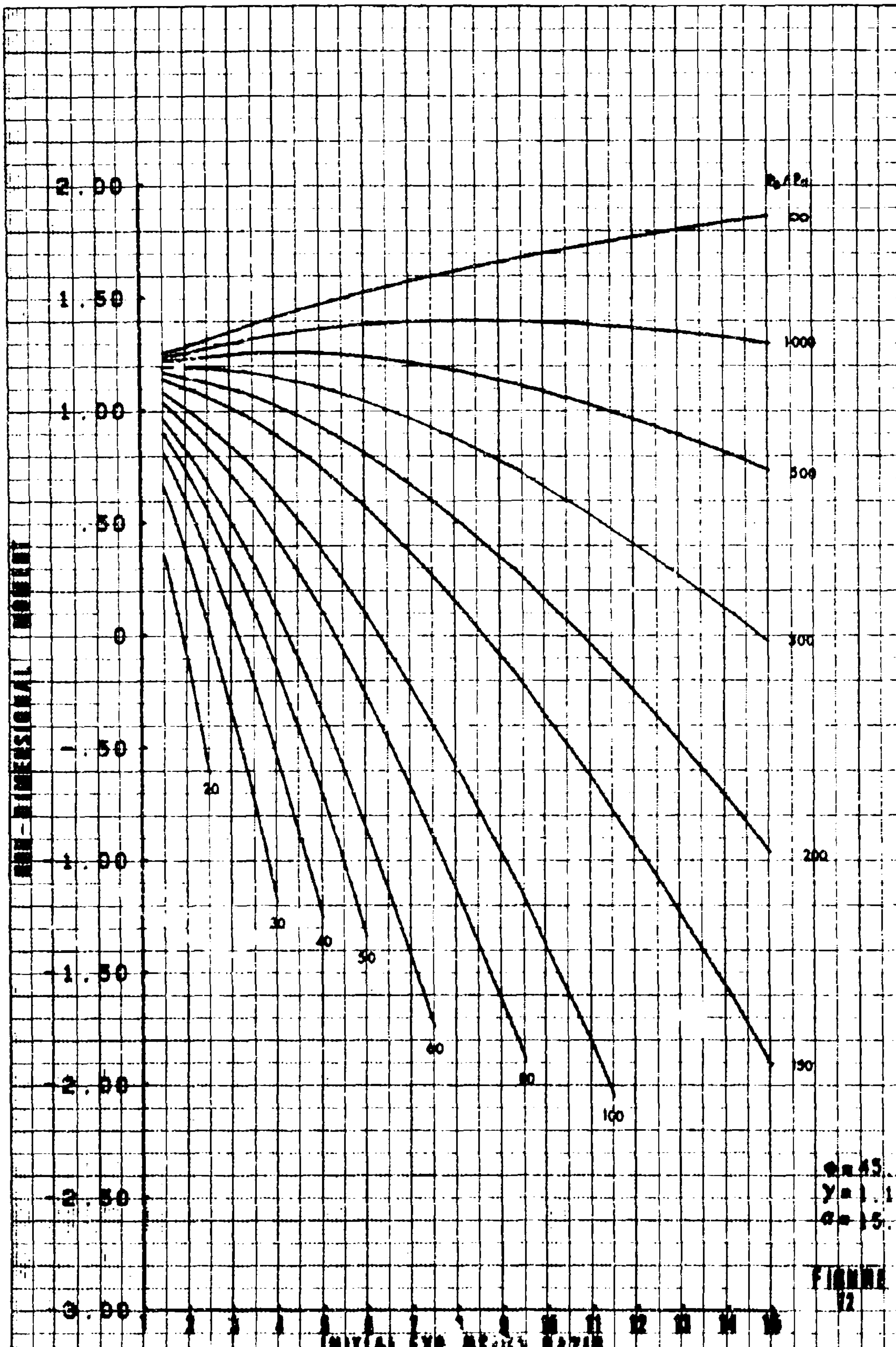

THRUST DEFLECTION ANGLE DEGREES
INITIAL EXPANSION RATIO
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0
-2.0
-4.0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
∞
1000
500
200
150
100
80
60
50
40
30
20

FIGURE 21


2.00
1.50
1.00
.50
0
-.50
-1.00
-1.50
-2.00
-2.50
-3.00
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
INITIAL EXPANSION RATIO
NON-DIMENSIONAL MOMENT
P_o/P_a
1000
500
300
200
150
100
80
60
50
40
30
20

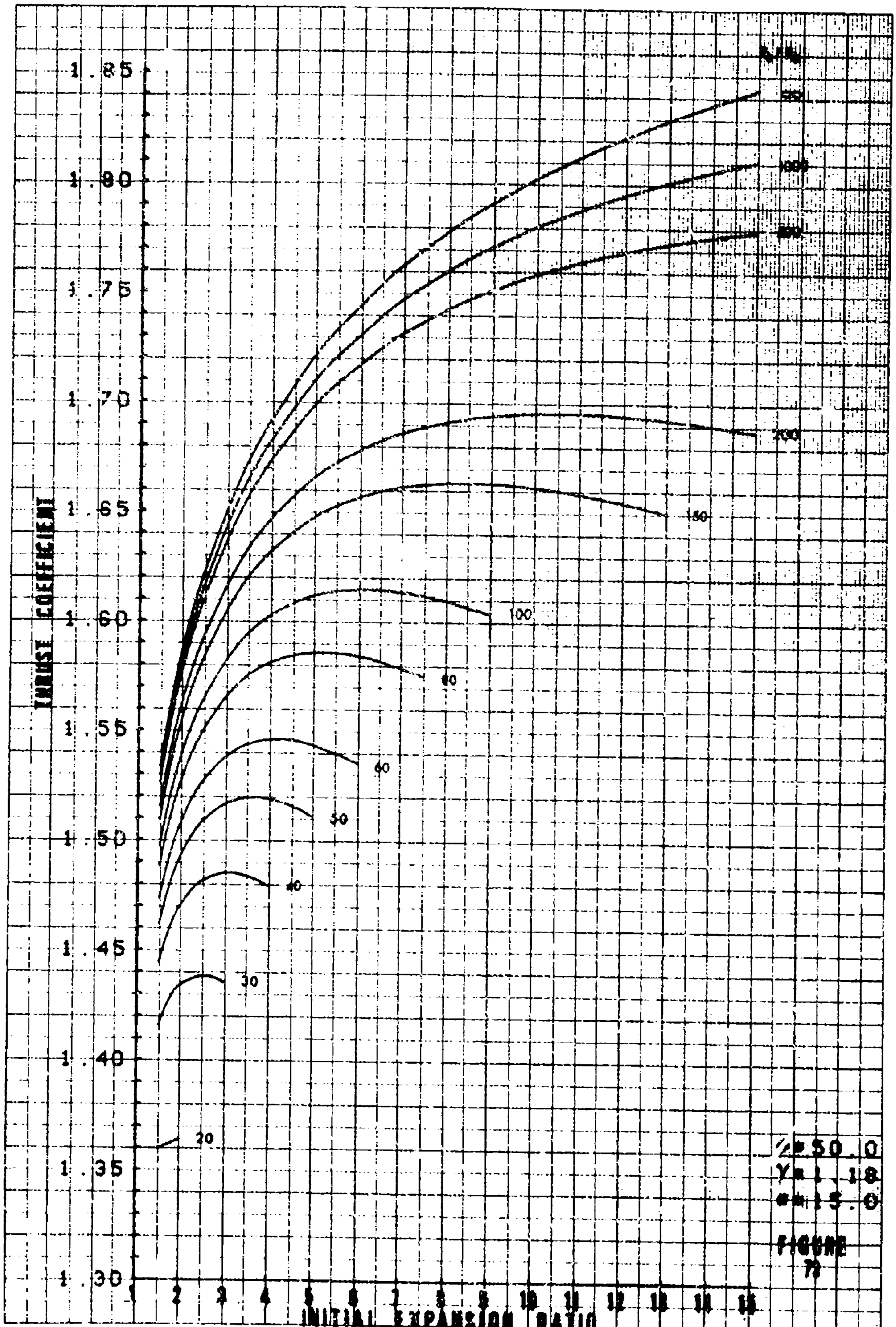

THRUST COEFFICIENT
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
INITIAL EXPANSION RATIO
1000
200
150
100
80
60
50
40
30
20
50.0
1.18
15.0

FIGURE 73

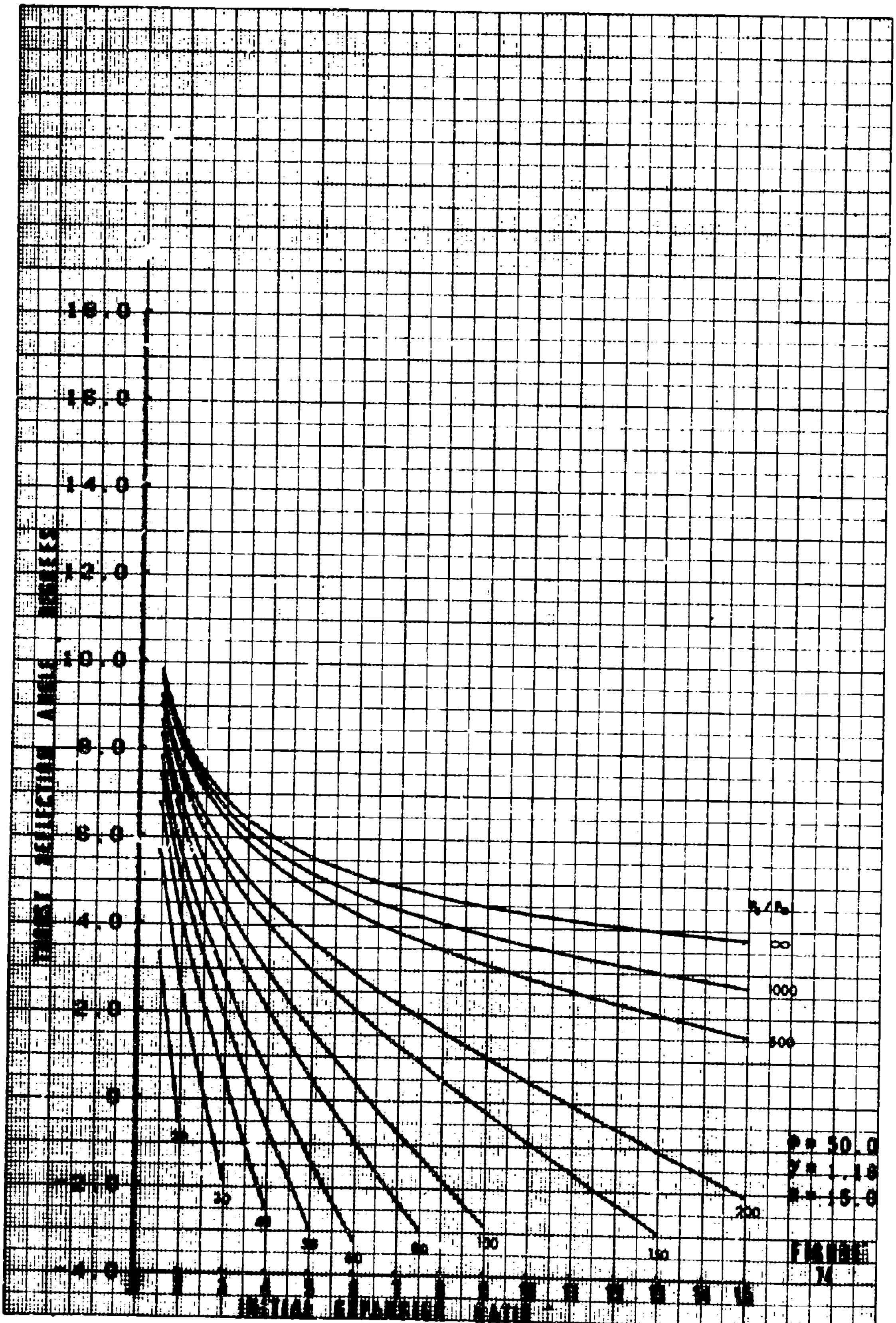
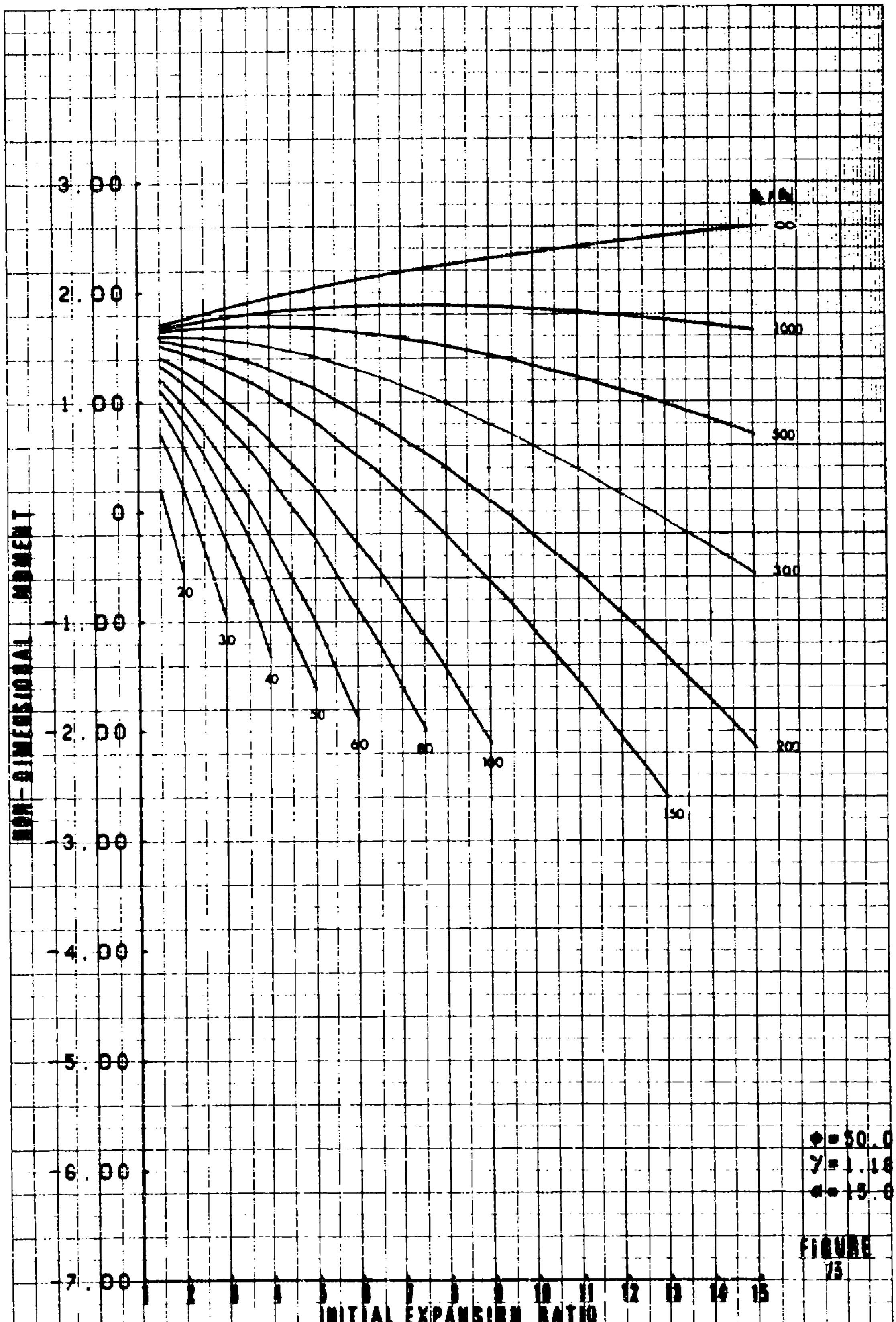
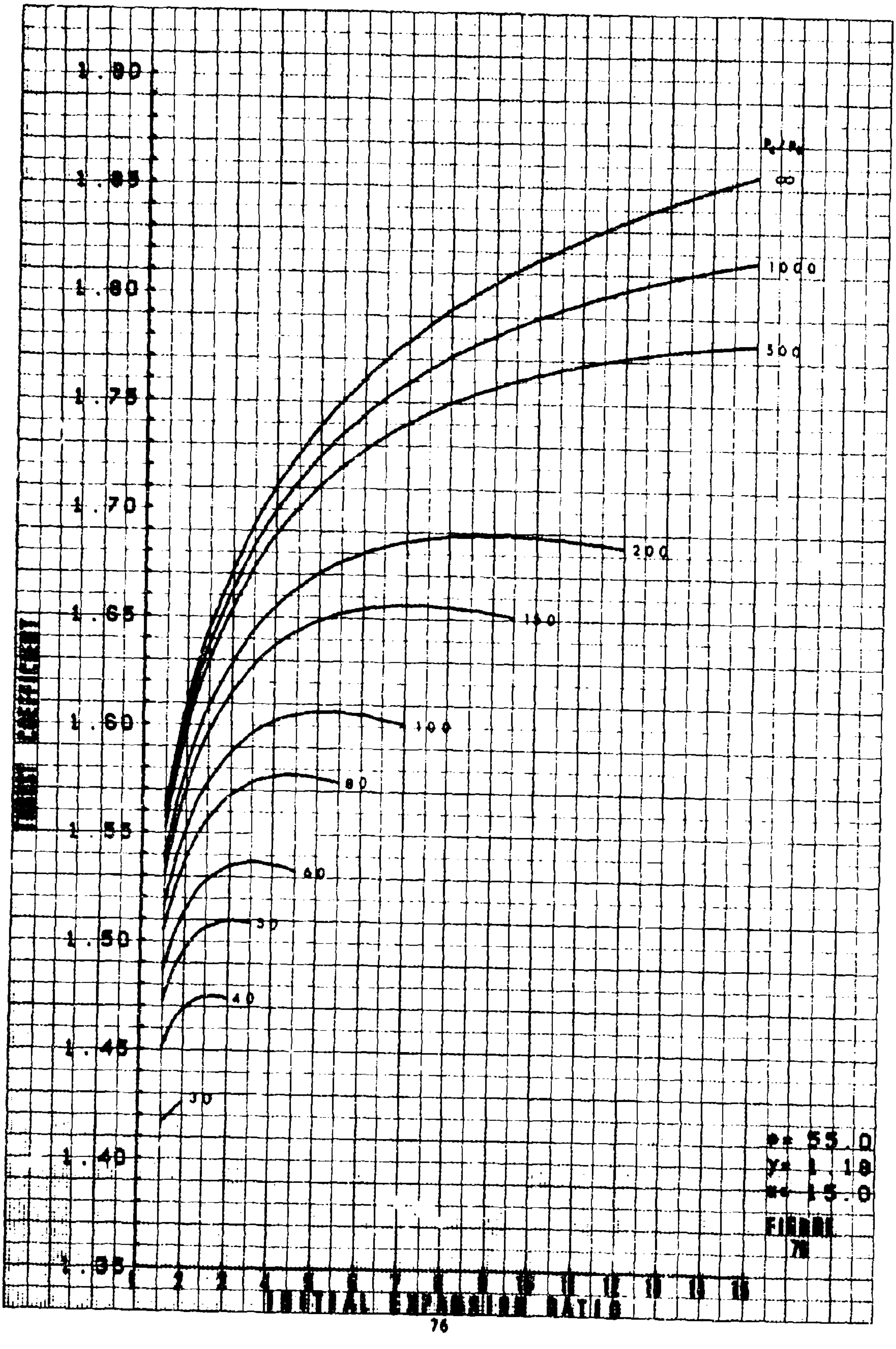

THRUST DEFLECTION ANGLE, DEGREES
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0
-2.0
-4.0
INITIAL EXPANSION RATIO
∞
1000
500
200
150
100
80
60
50
40
30
20

FIGURE 74


NON-DIMENSIONAL MOMENT
3.00
2.00
1.00
0
-1.00
-2.00
-3.00
-4.00
-5.00
-6.00
-7.00
∞
1000
500
300
200
150
100
80
60
50
40
30
20
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
INITIAL EXPANSION RATIO
φ = 50.0
γ = 1.18
α = 15.0
FIGURE
73



1.90
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
THRUST COEFFICIENT
P_c/P_a
∞
1000
500
200
150
100
80
60
50
40
30
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
θ= 55.0
γ= 1.18
ε= 15.0
FIGURE 78

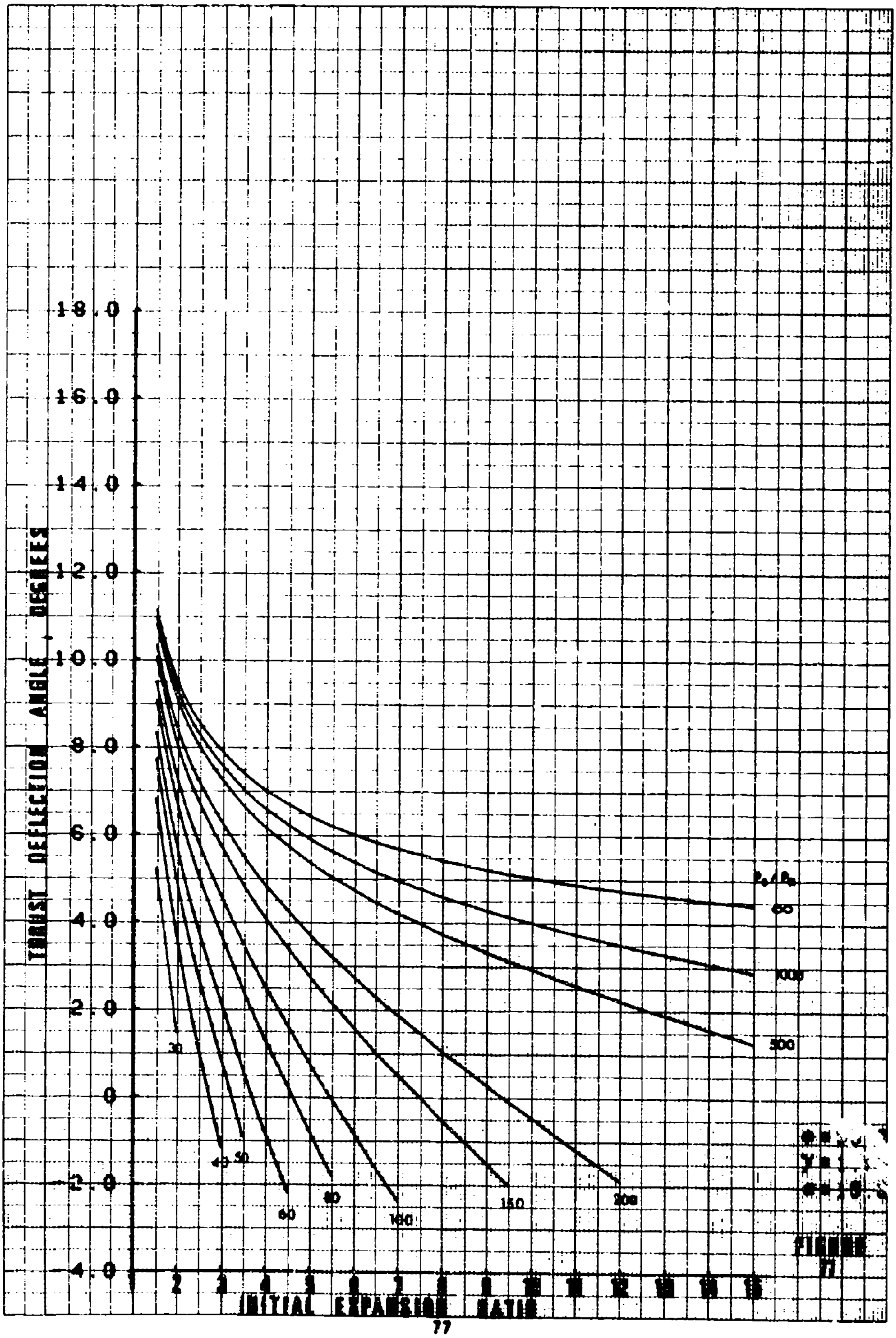
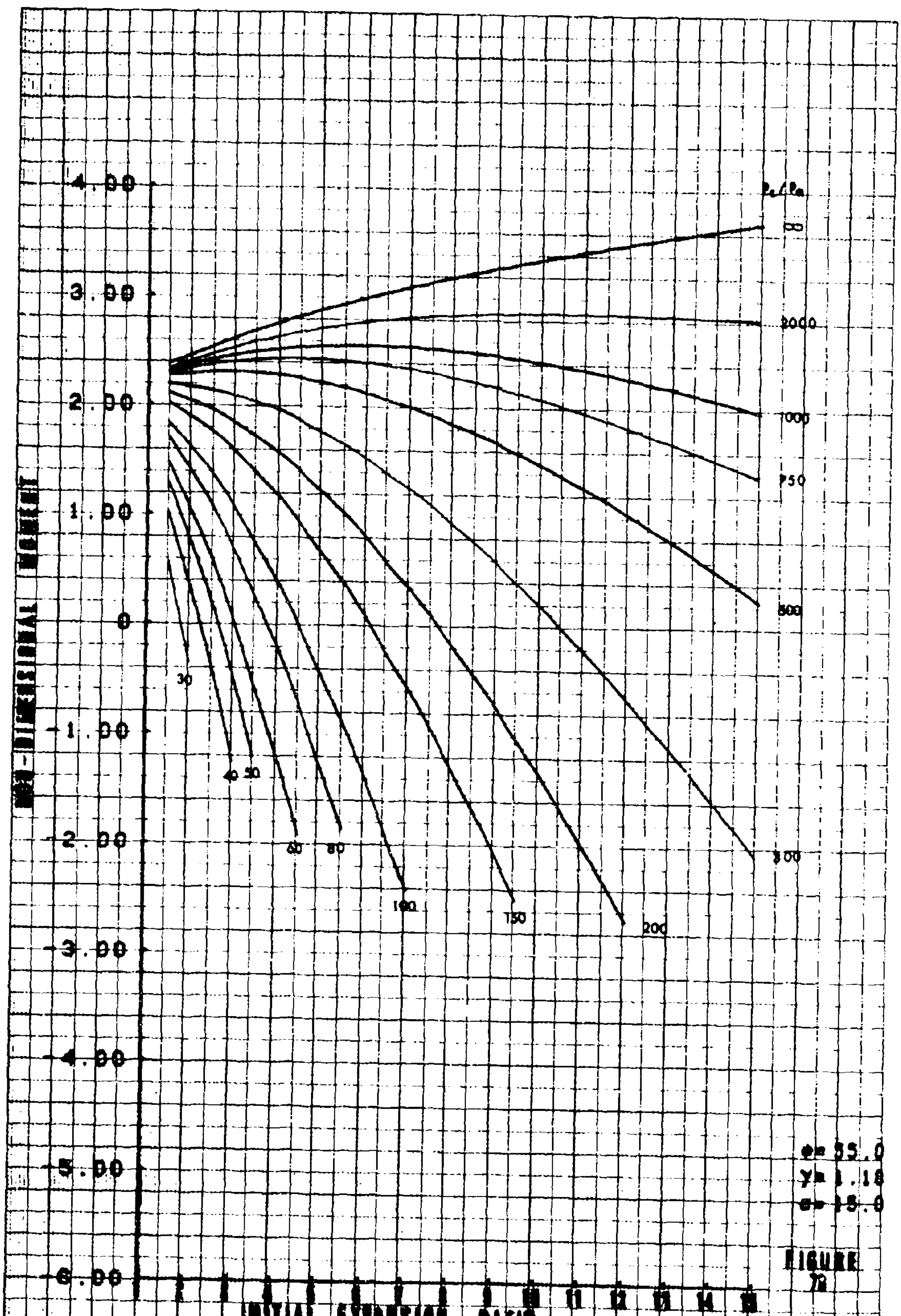
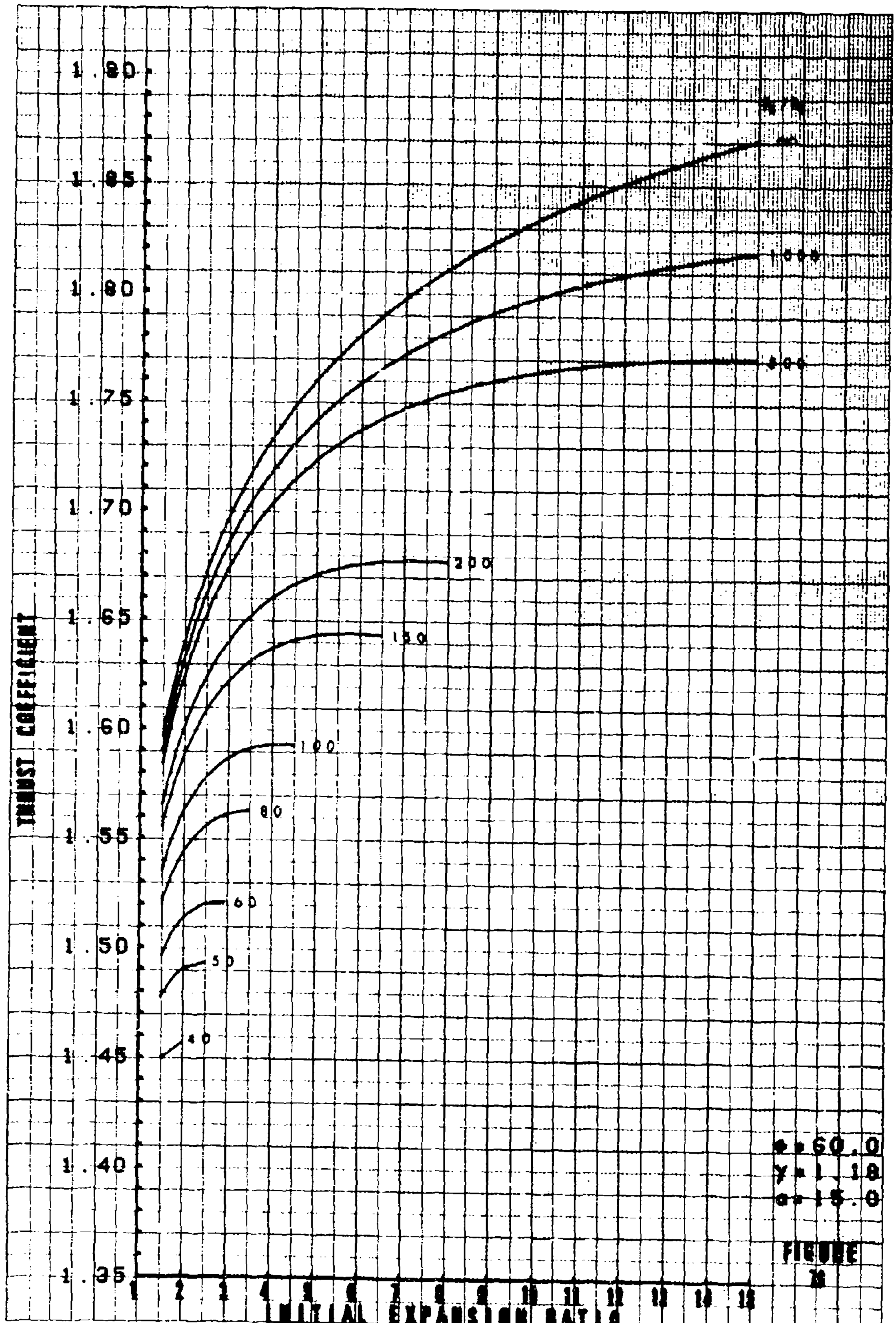

18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0
-2.0
-4.0
THRUST DEFLECTION ANGLE, DEGREES
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
INITIAL EXPANSION RATIO
∞
1000
500
30
40
50
60
80
100
150
200

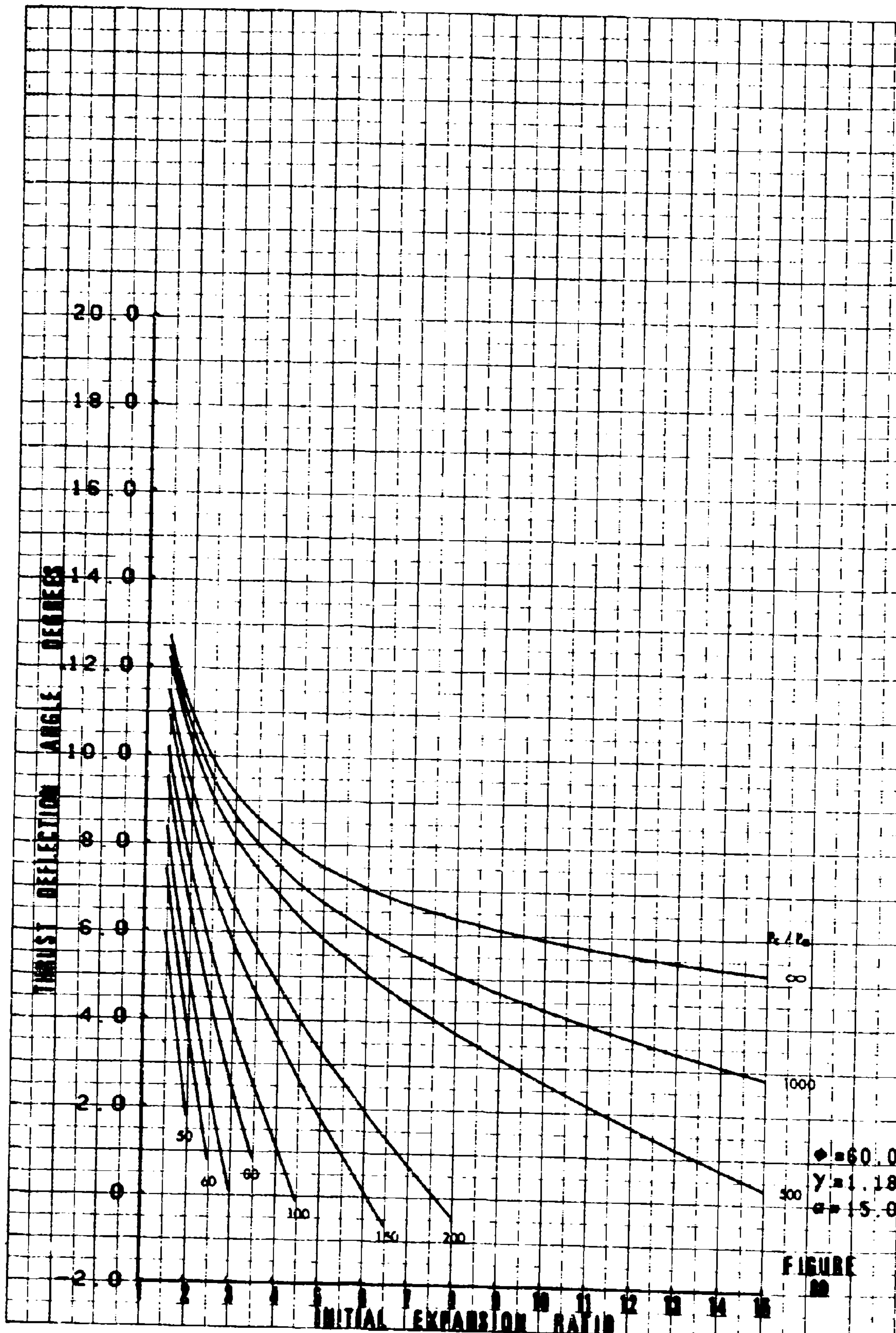
FIGURE 77

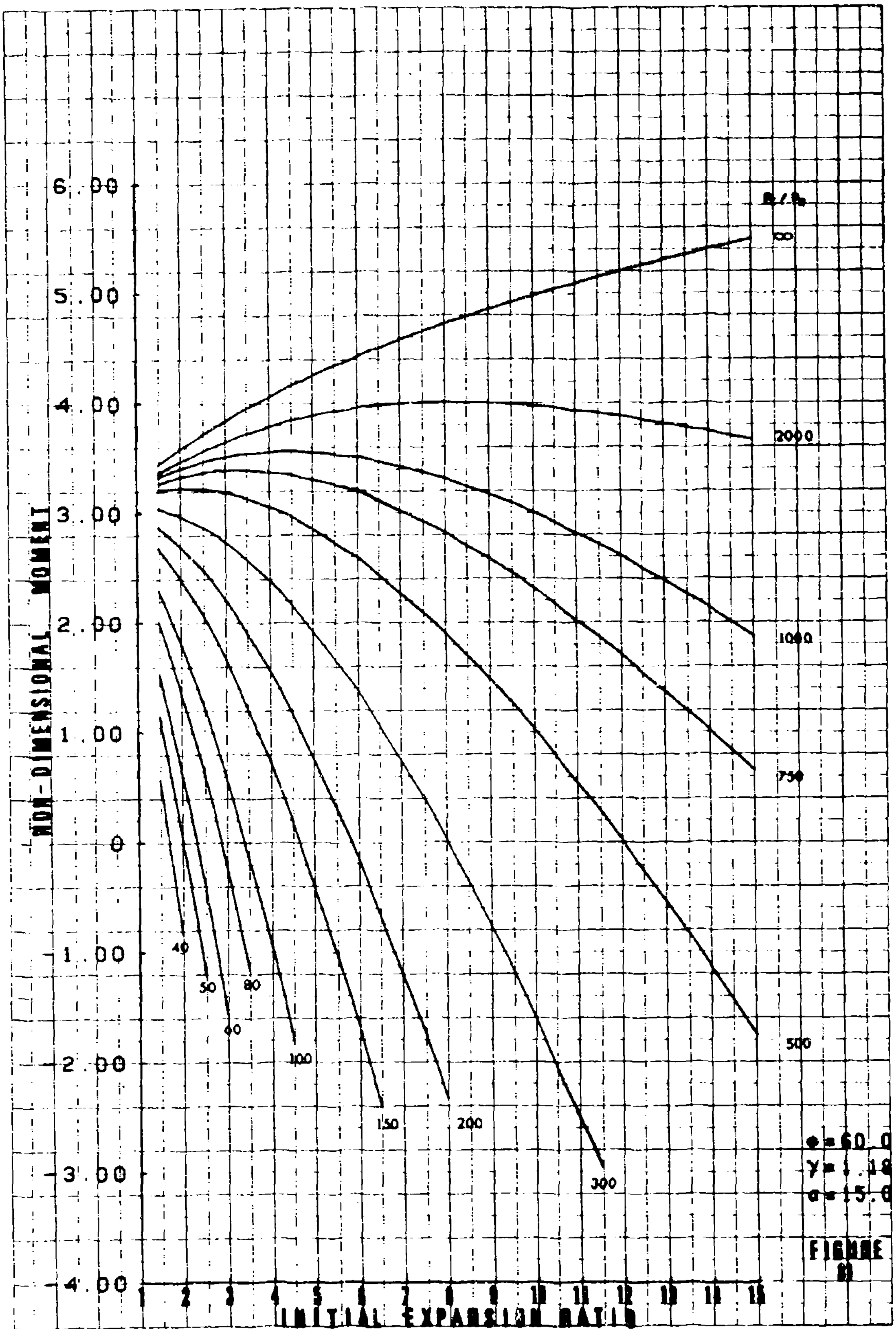


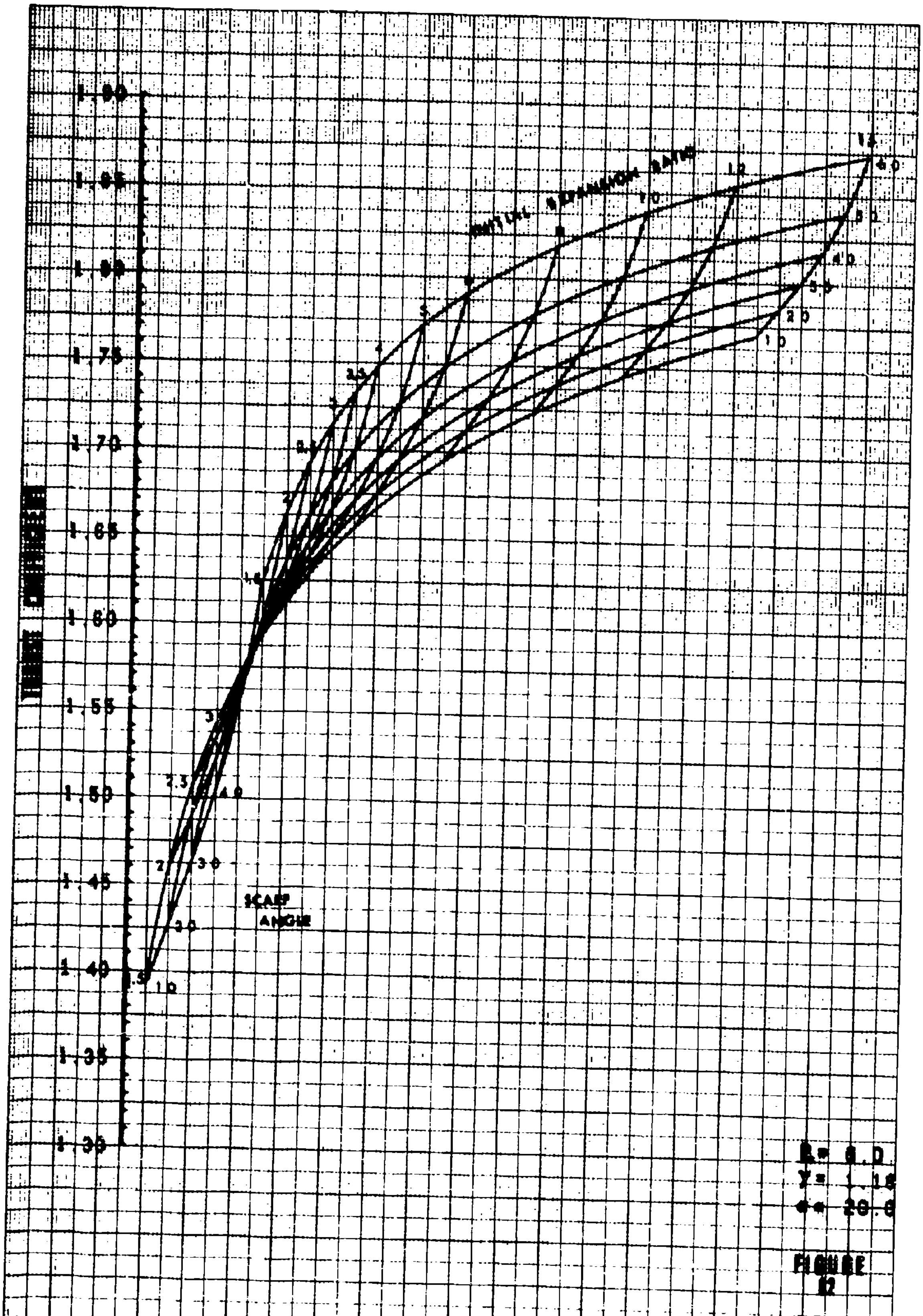
NON-DIMENSIONAL MOMENT
INITIAL EXPANSION RATIO
4.00
3.00
2.00
1.00
0
-1.00
-2.00
-3.00
-4.00
-5.00
-6.00
2
3
4
5
6
7
8
9
10
11
12
13
14
15
P_c/P_a
∞
2000
1000
750
500
300
200
150
100
80
60
40
50
30
γ= 1.18

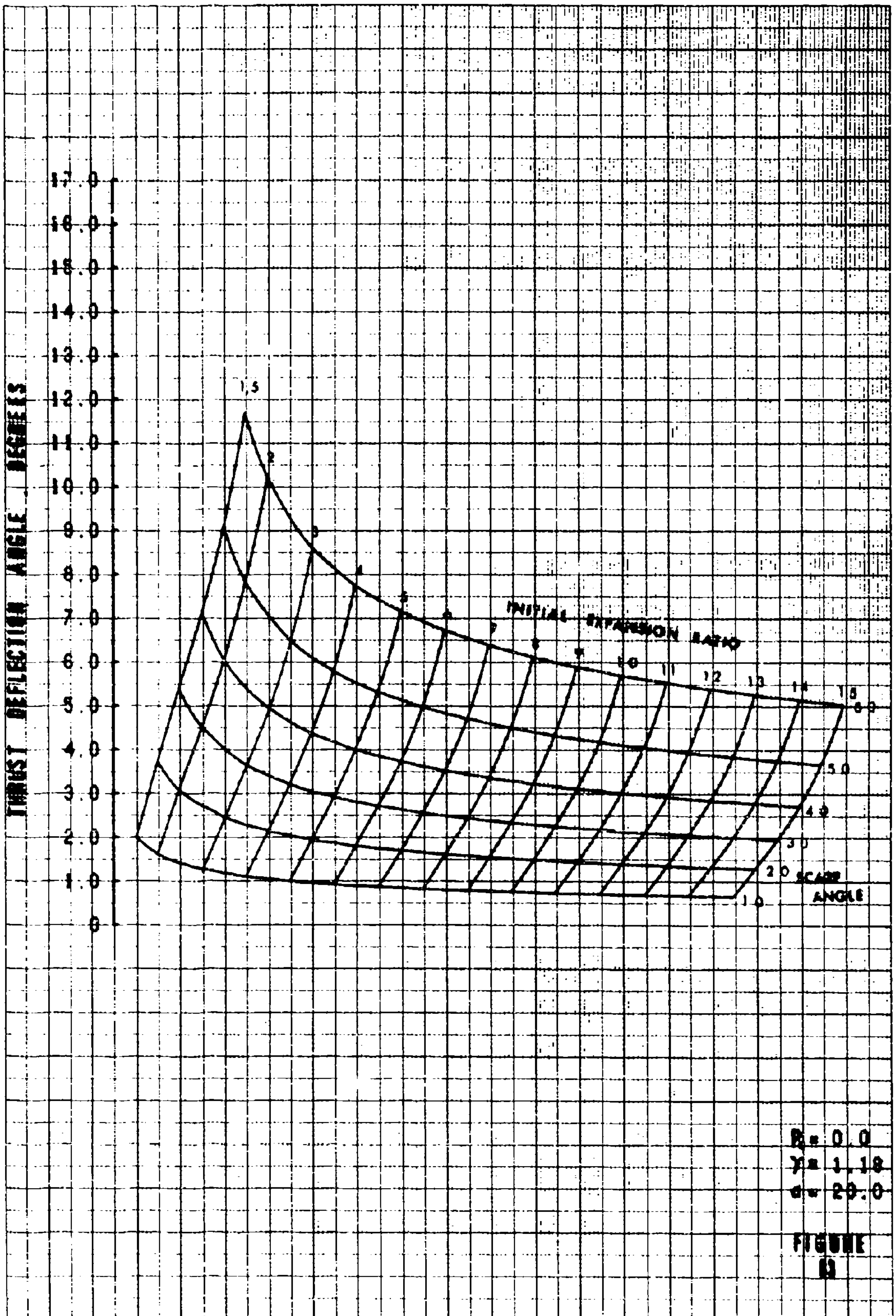
FIGURE 72


THRUST COEFFICIENT
1.90
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
INITIAL EXPANSION RATIO
1000
500
200
150
100
80
60
50
40
γ = 1.18
α = 15.0
FIGURE

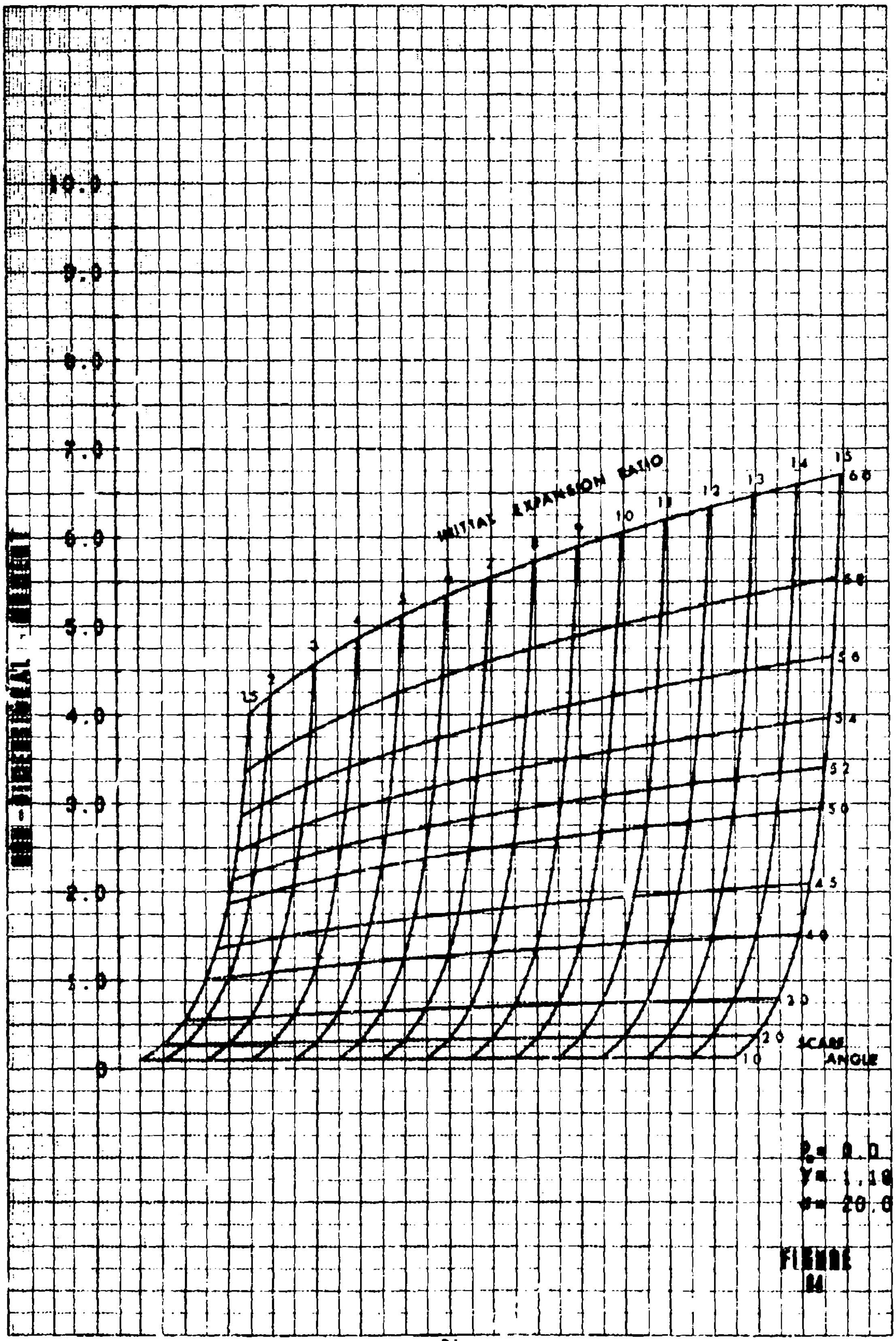

20.0
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0
-2.0
THRUST DEFLECTION ANGLE DEGREES
INITIAL EXPANSION RATIO
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
P_c/P_a
∞
1000
500
50
60
68
100
150
200
ϕ = 60.0
γ = 1.18
α = 15.0
FIGURE 30


NON-DIMENSIONAL MOMENT
6.00
5.00
4.00
3.00
2.00
1.00
0
-1.00
-2.00
-3.00
-4.00
INITIAL EXPANSION RATIO
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
R/R₀
∞
2000
1000
750
500
300
200
150
100
80
60
50
40
φ = 60.0
γ = 1.18
α = 15.0
FIGURE

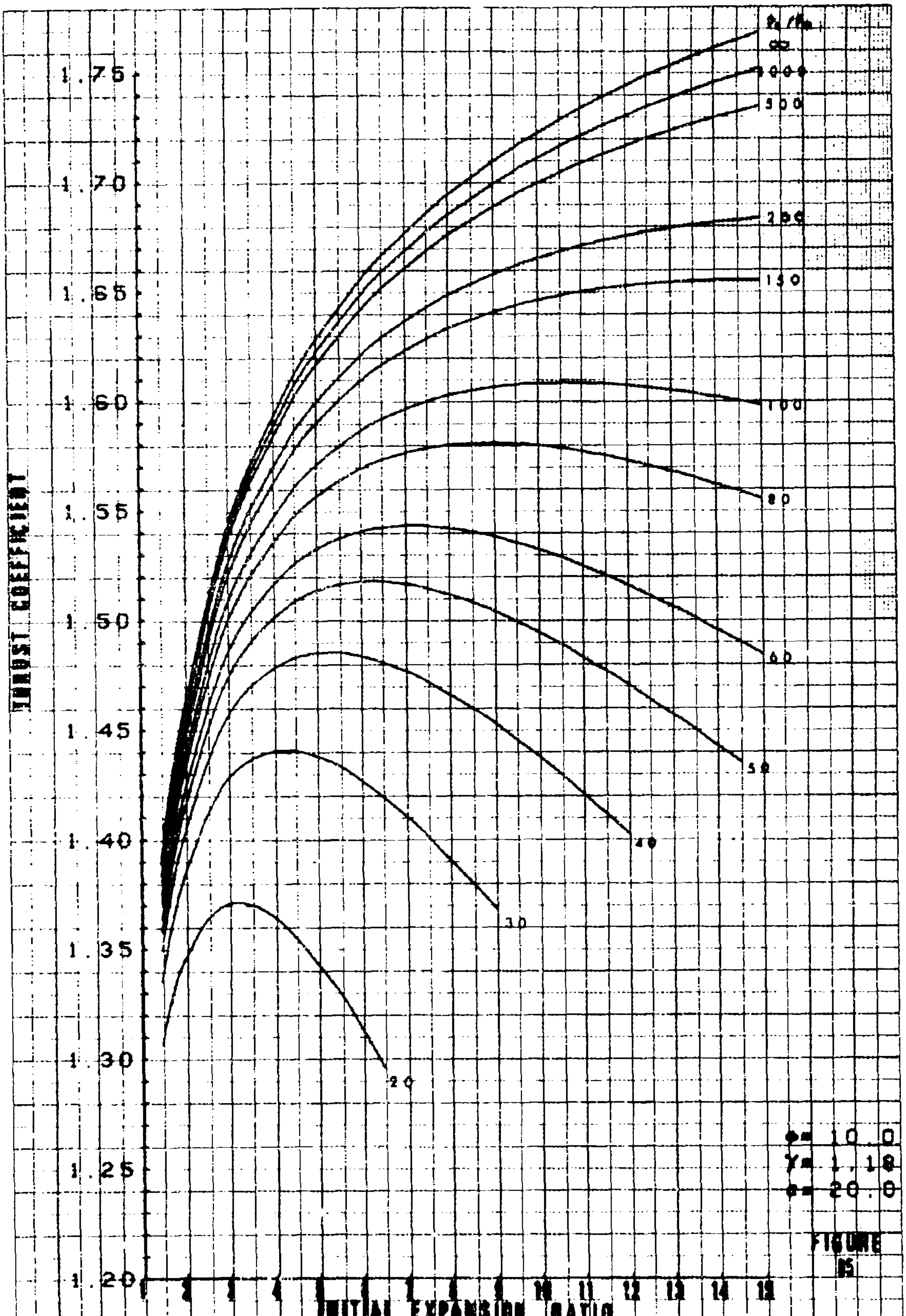

1.80
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
INITIAL EXPANSION RATIO
SCARF ANGLE
FIGURE
82



THRUST DEFLECTION ANGLE, DEGREES
INITIAL EXPANSION RATIO
SCARF ANGLE

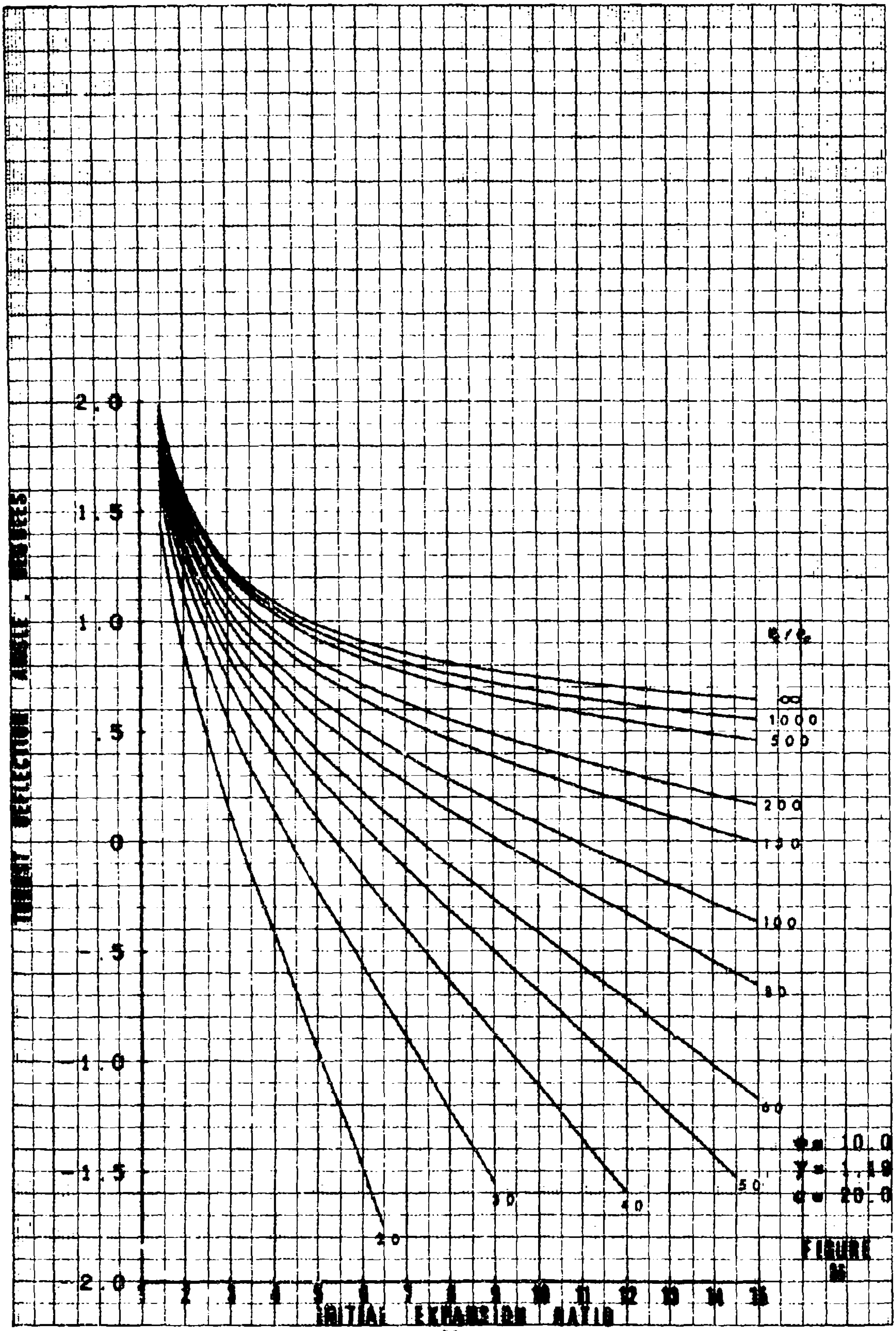


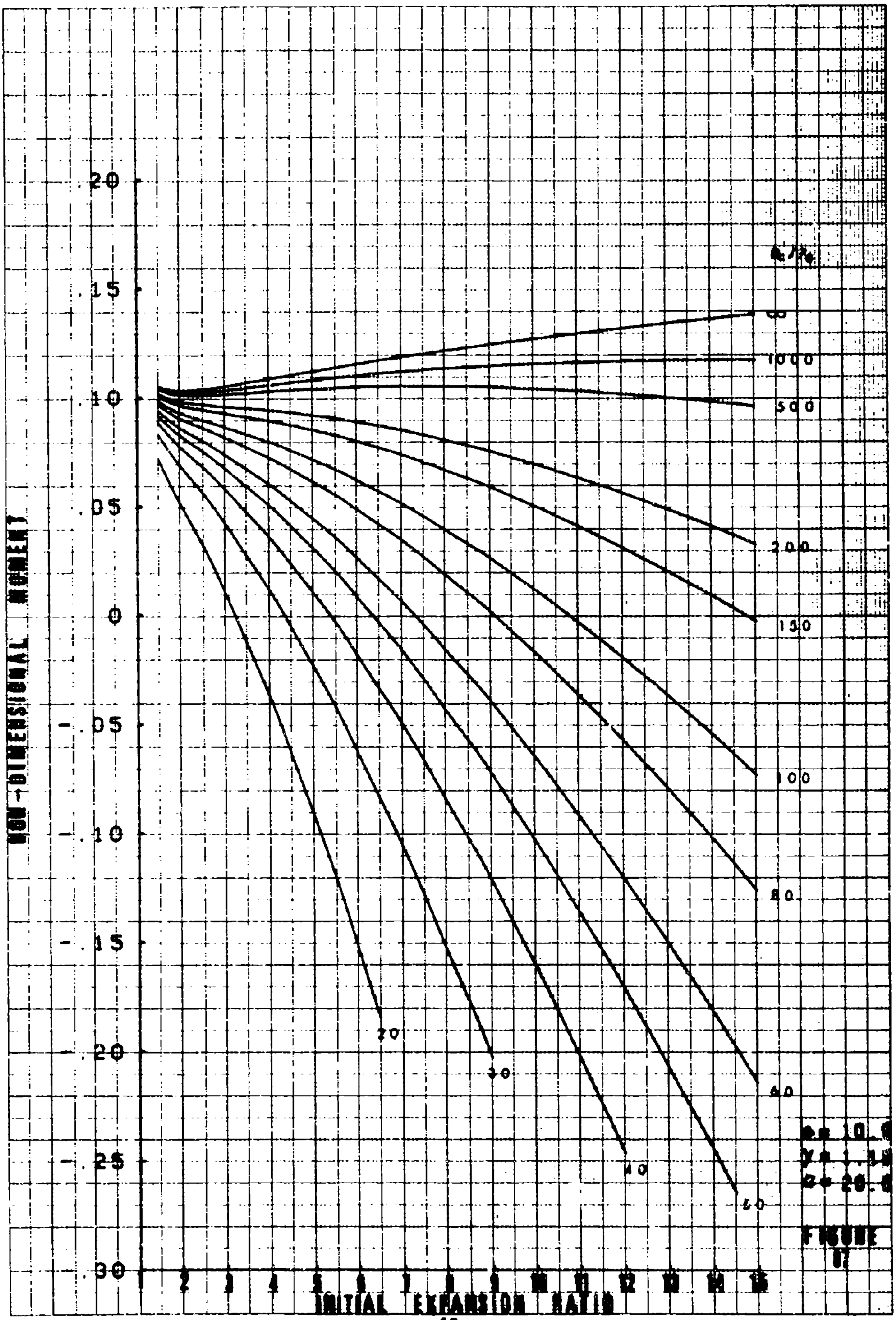
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
INITIAL EXPANSION RATIO
1.5
2
3
4
5
6
7
8
9
10
11
12
13
14
15
60
58
56
54
52
50
45
40
30
20
10
SCARF ANGLE

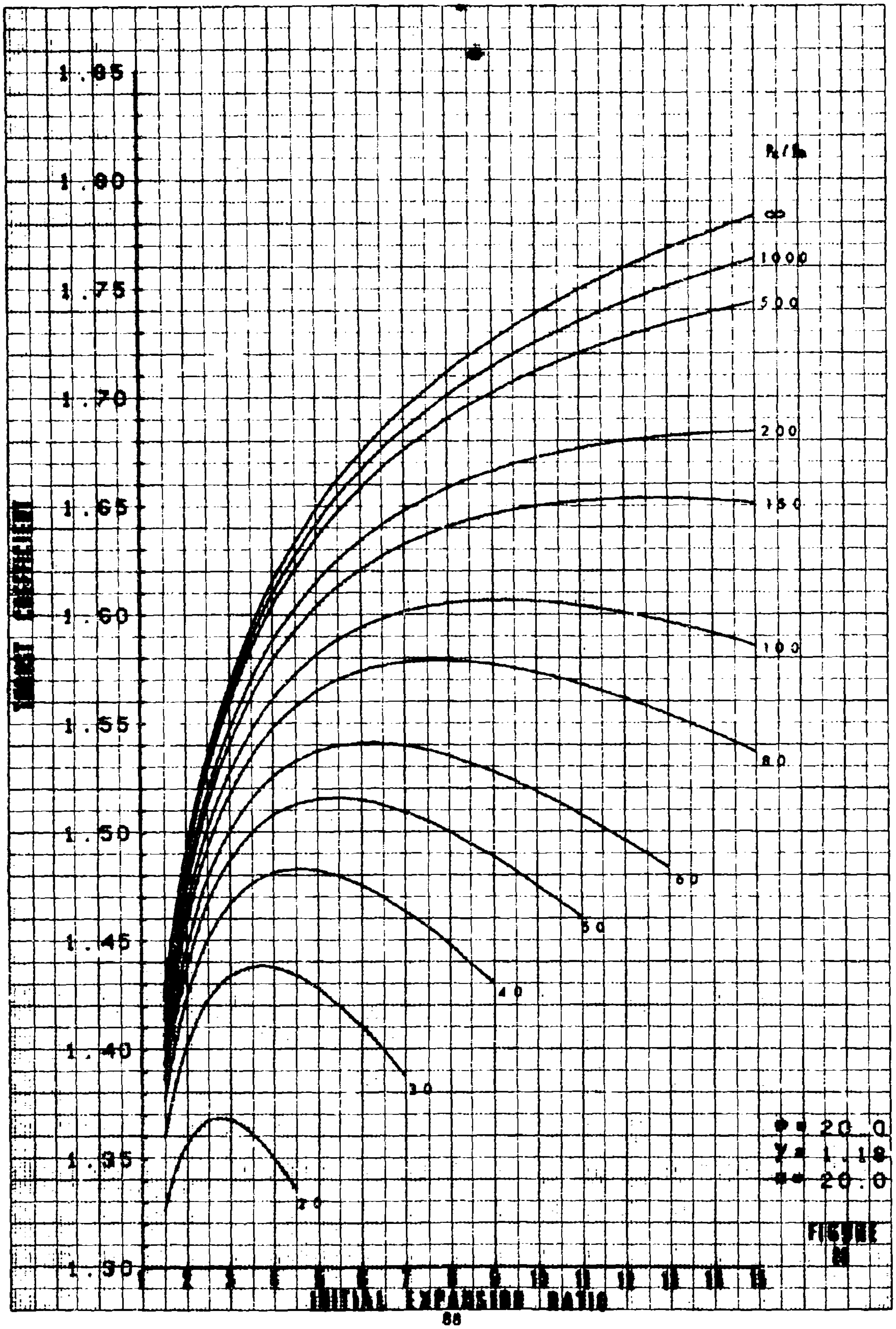


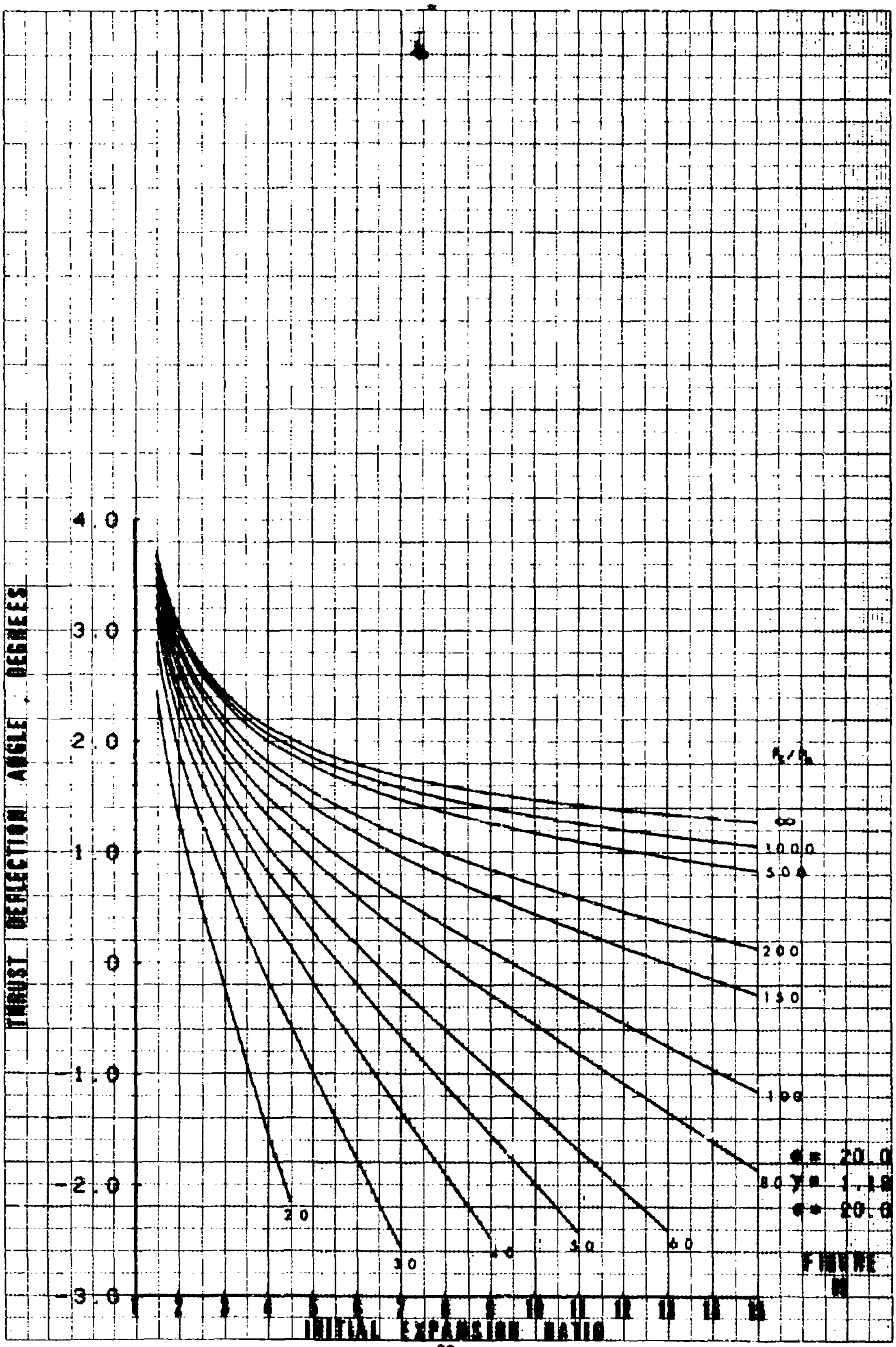
P_c/P_a
∞
1000
500
200
150
100
80
60
50
40
30
20
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
1.25
1.20
THRUST COEFFICIENT
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
φ= 10.0
γ= 1.18
θ= 20.0

FIGURE 85

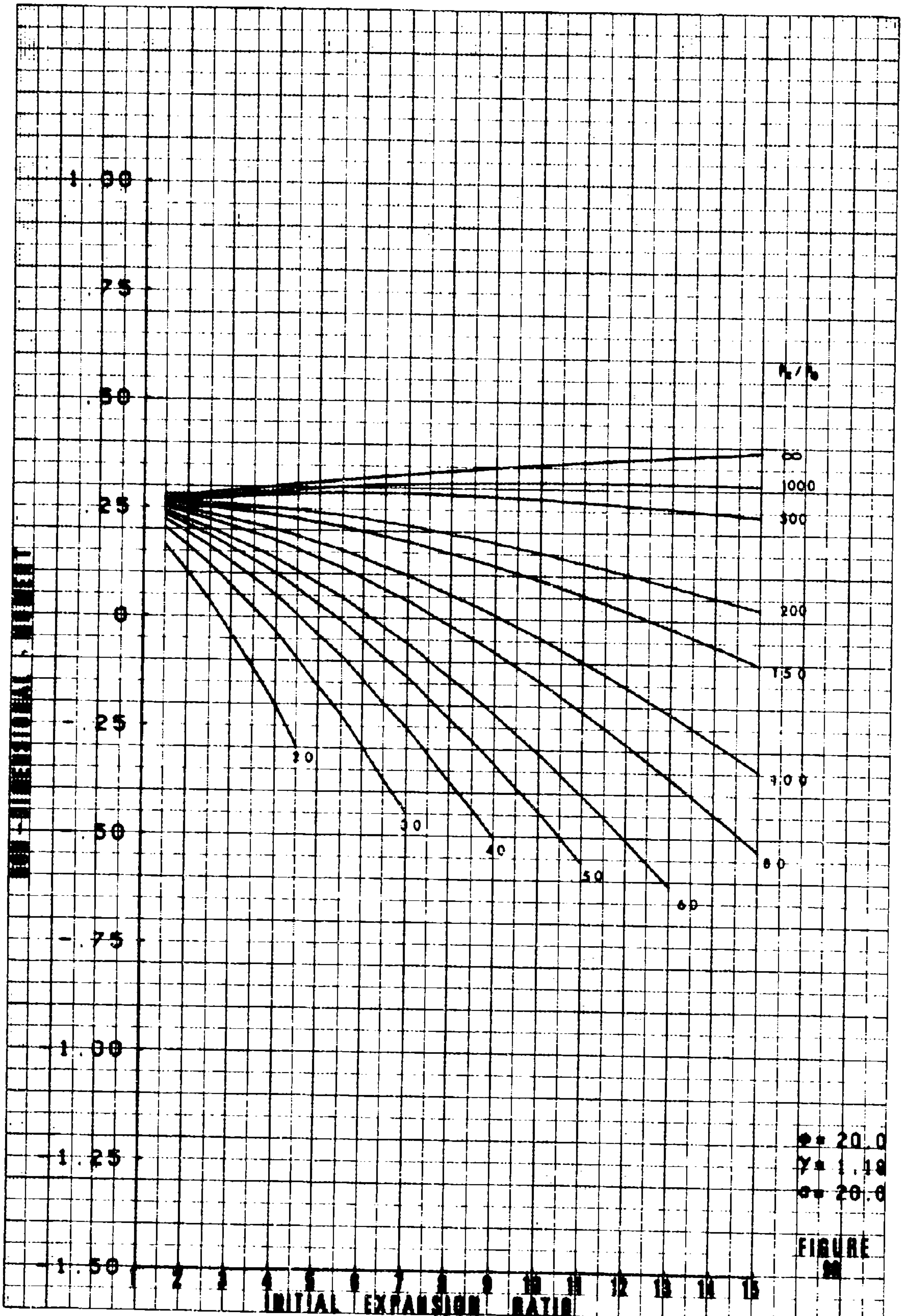

2.0
1.5
1.0
.5
0
-.5
-1.0
-1.5
-2.0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
∞
1000
500
200
150
100
80
60
50
40
30
20
10.0
20.0
FIGURE


.20
.15
.10
.05
0
-.05
-.10
-.15
-.20
-.25
-.30
NON-DIMENSIONAL MOMENT
∞
1000
500
200
150
100
80
60
50
40
30
20
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
INITIAL EXPANSION RATIO
FIGURE

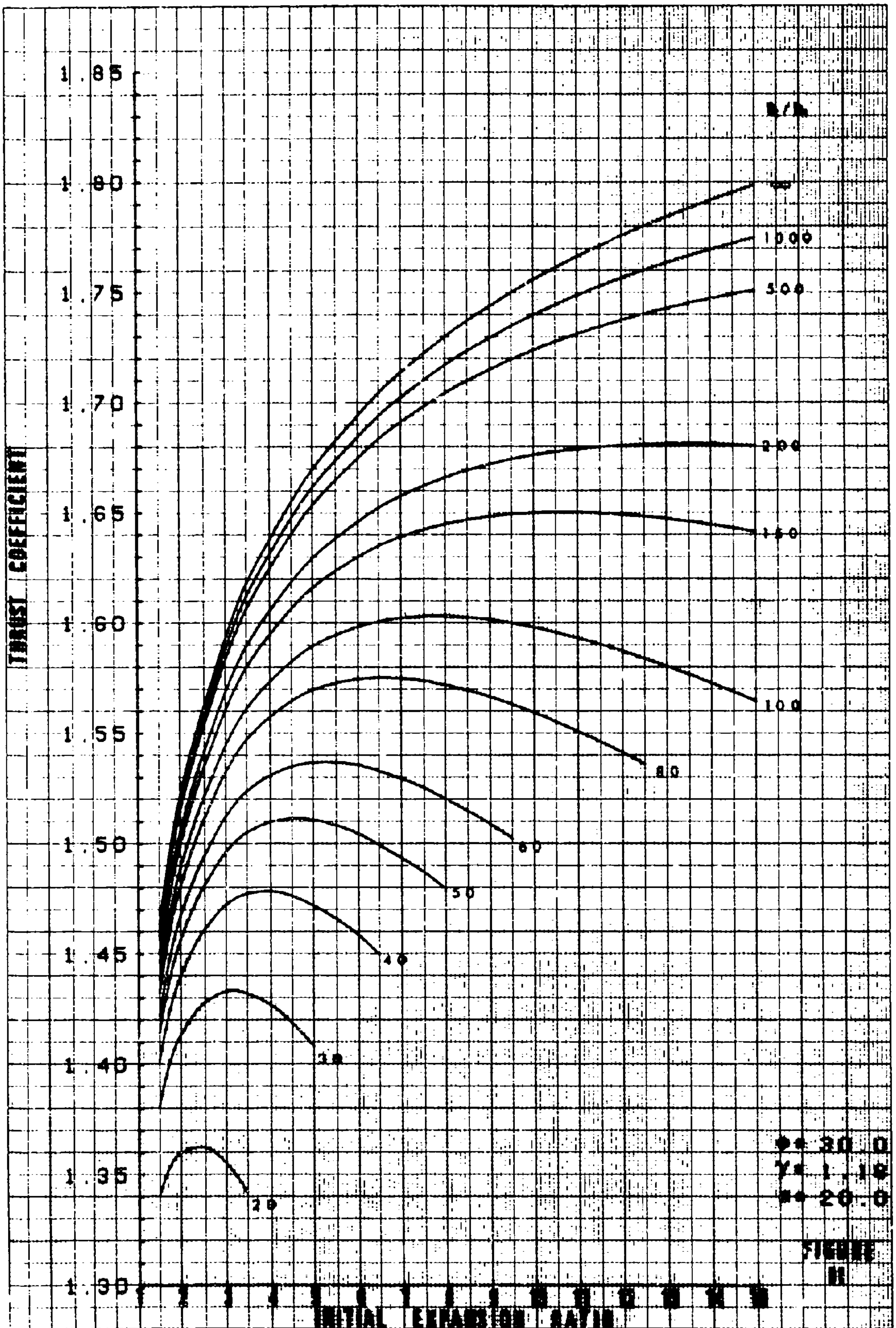

1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
THRUST COEFFICIENT
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
∞
1000
500
200
150
100
80
60
50
40
30
20
20.0
1.18
20.0
FIGURE

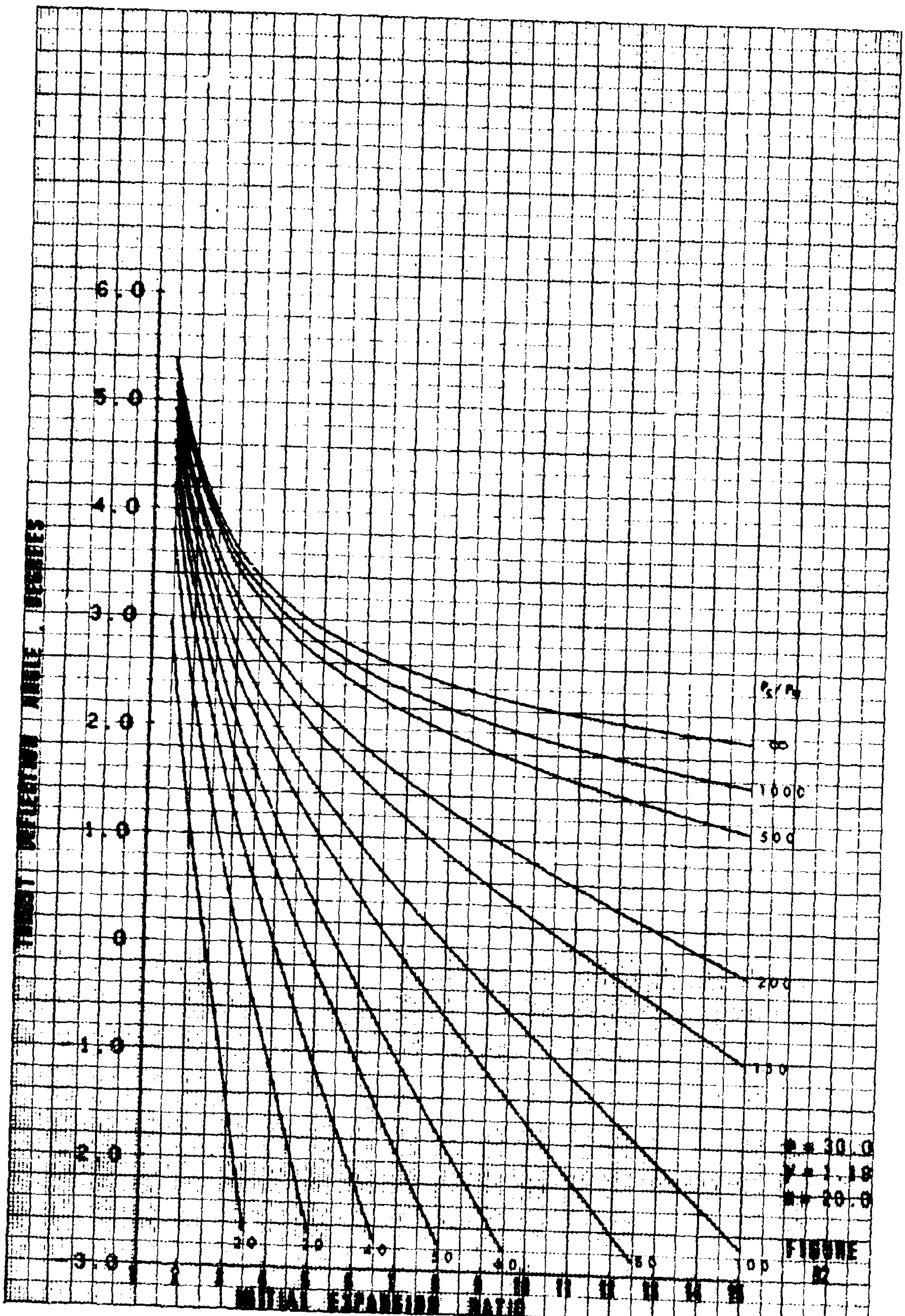


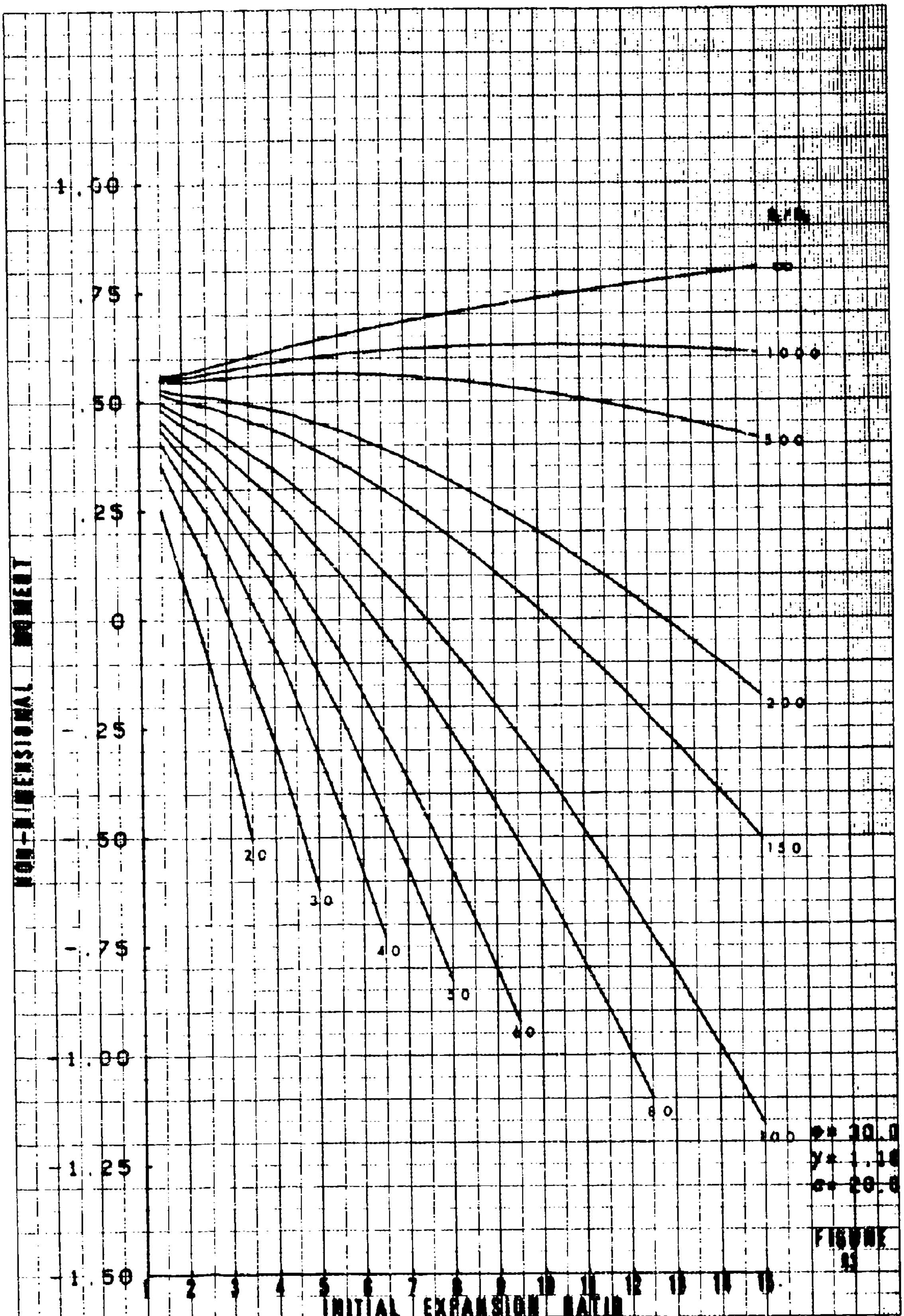
THRUST DEFLECTION ANGLE, DEGREES
4.0
3.0
2.0
1.0
0
-1.0
-2.0
-3.0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
INITIAL EXPANSION RATIO
∞
1000
500
200
150
100
80
60
50
40
30
20
20.0
20.0
FIGURE

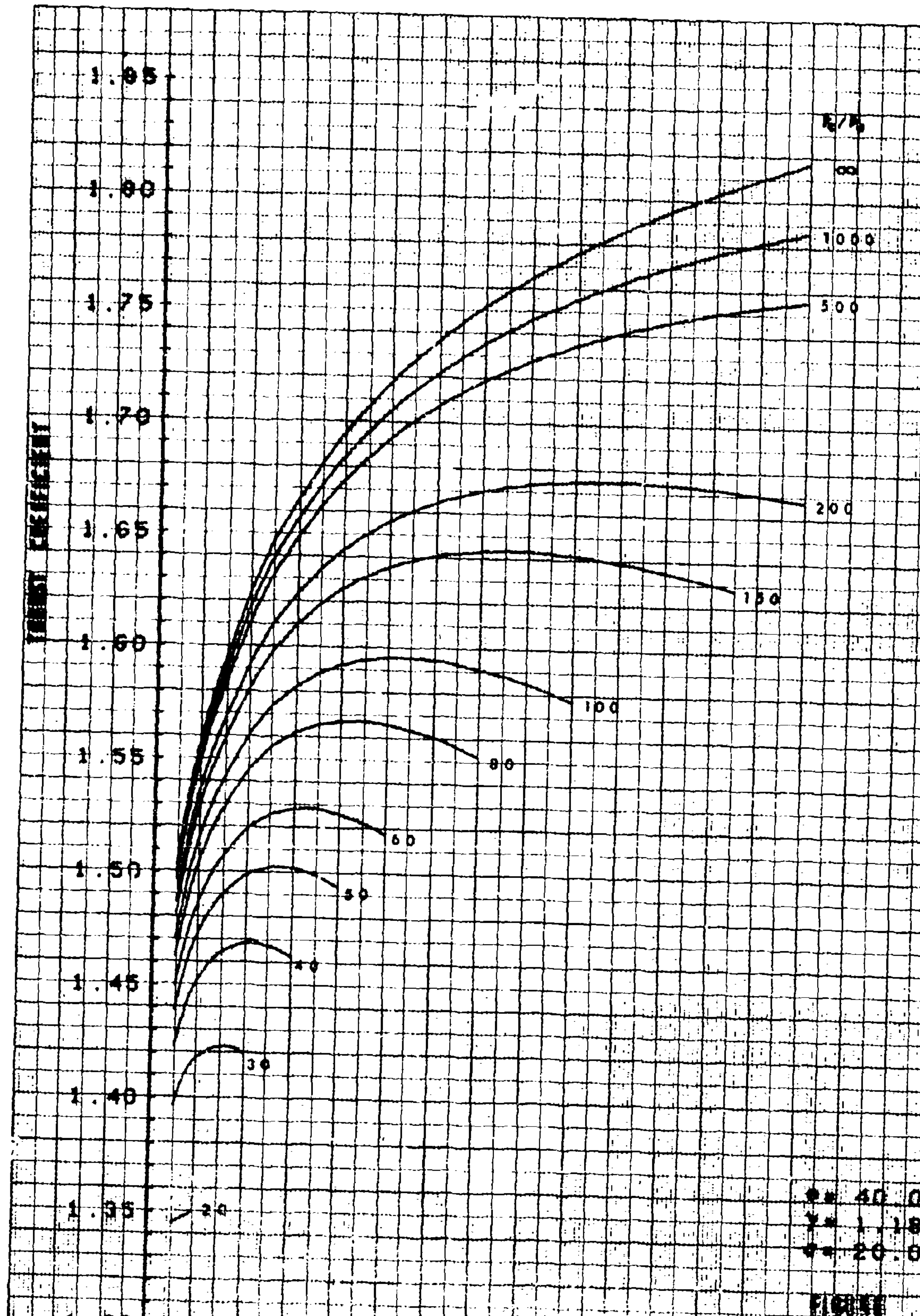


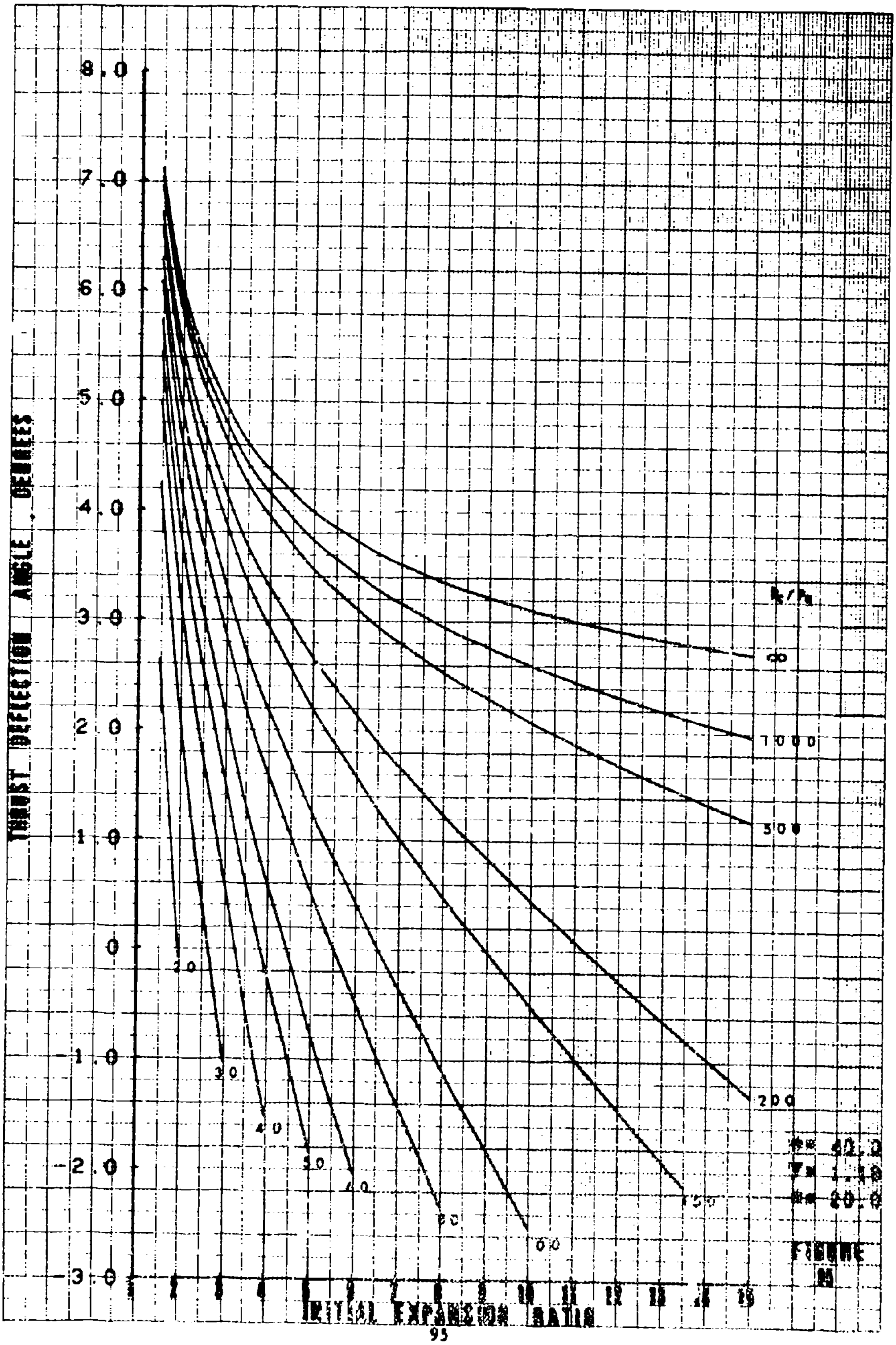
1.00
.75
.50
.25
0
-.25
-.50
-.75
-1.00
-1.25
-1.50
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
∞
1000
300
200
150
100
80
60
50
40
30
20

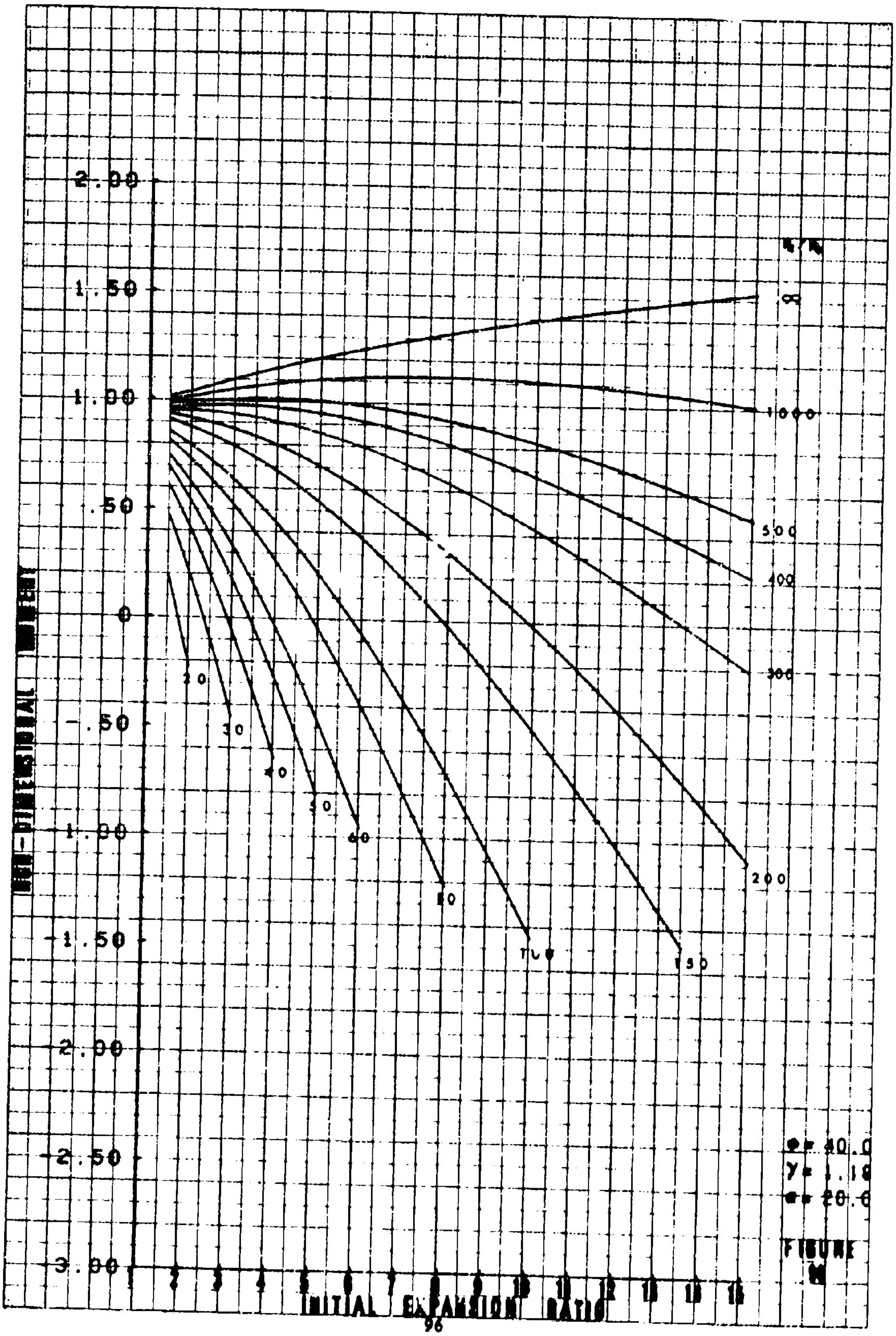

THRUST COEFFICIENT
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
1000
500
200
150
100
80
60
50
40
30
20
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
INITIAL EXPANSION RATIO
Φ= 30.0
γ= 1.10
= 20.0
FIGURE 11

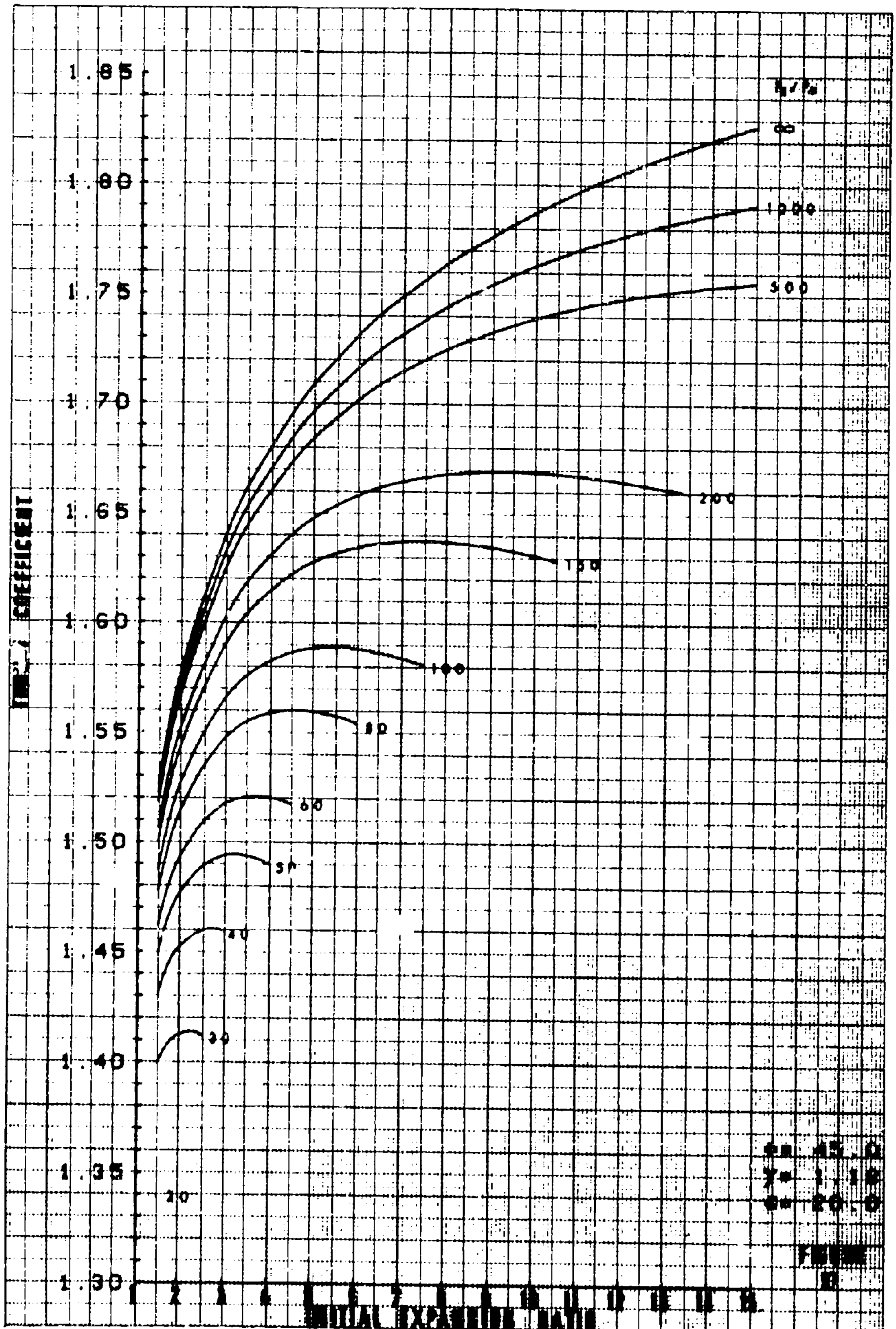

THRUST DEFLECTION ANGLE, DEGREES
INITIAL EXPANSION RATIO
6.0
5.0
4.0
3.0
2.0
1.0
0
-1.0
-2.0
-3.0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
P_S/P_N
∞
1000
500
200
100
20
30
40
50
60
80
100
= 30.0
= 1.18
= 20.0
FIGURE

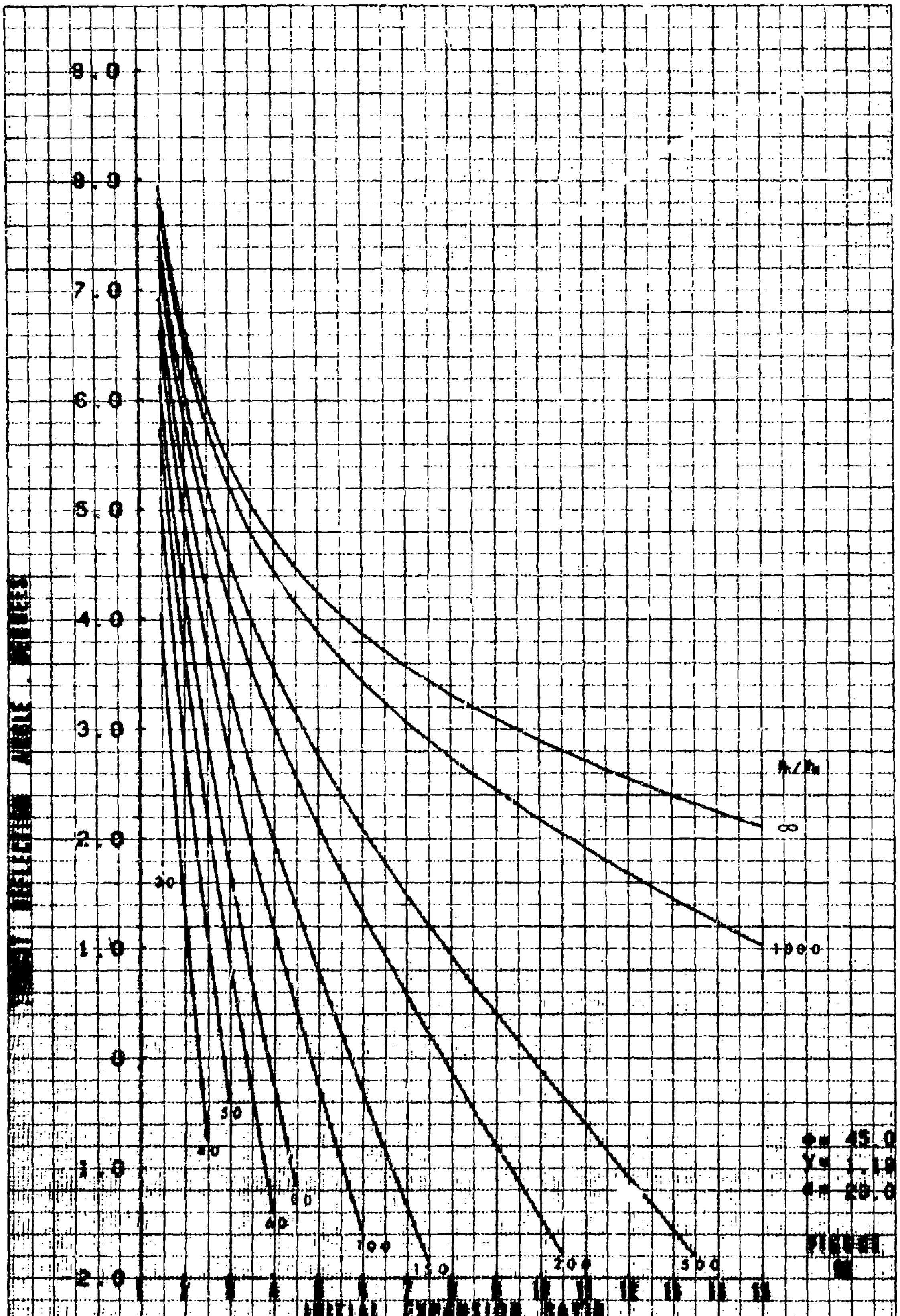

NON-DIMENSIONAL MOMENT
INITIAL EXPANSION RATIO
1.00
.75
.50
.25
0
-.25
-.50
-.75
-1.00
-1.25
-1.50
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
1000
500
200
150
100
80
60
50
40
30
20

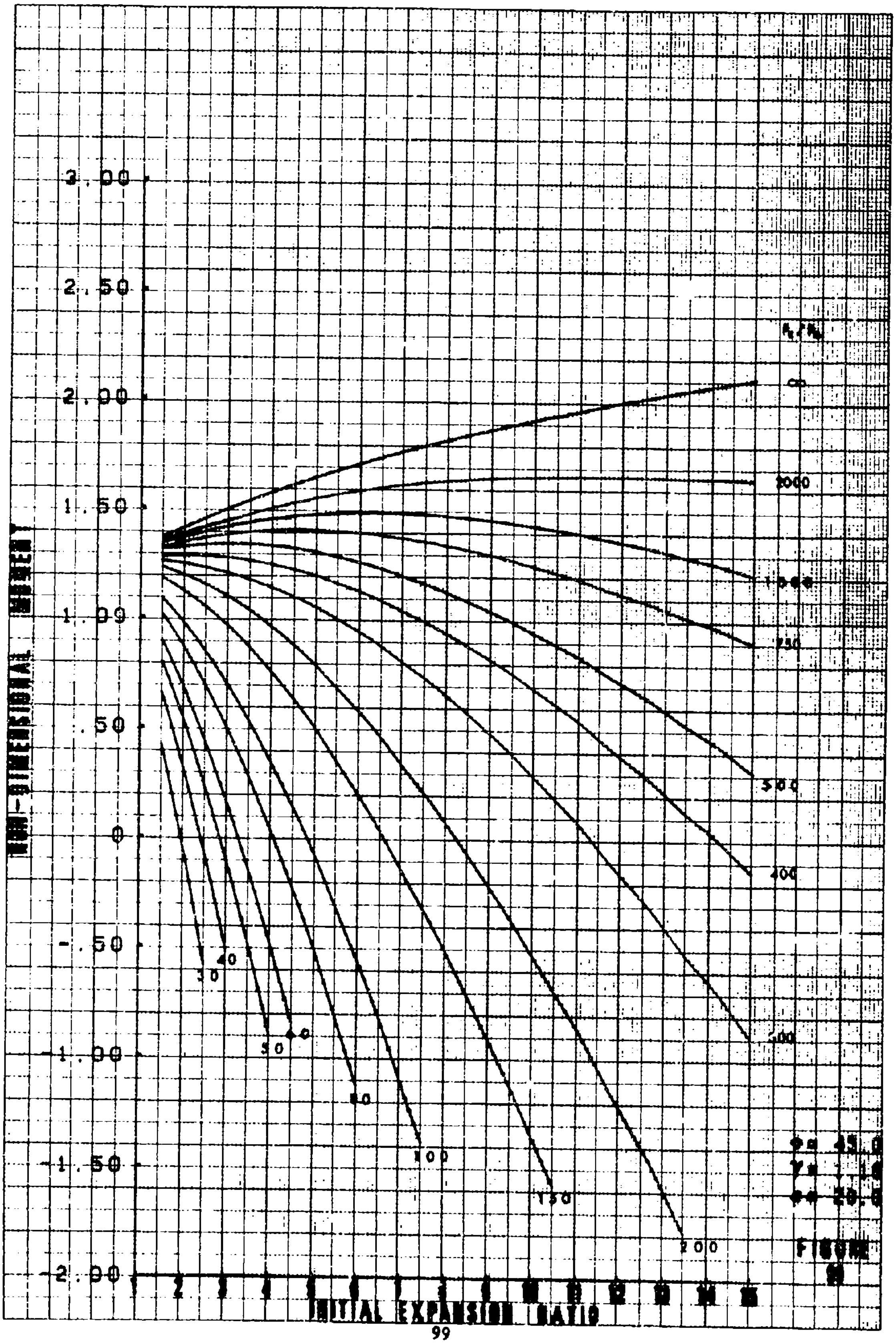

1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
THRUST COEFFICIENT
INITIAL EXPANSION RATIO
∞
1000
500
200
150
100
80
60
50
40
30
20
40.0
1.18
20.0
FIGURE

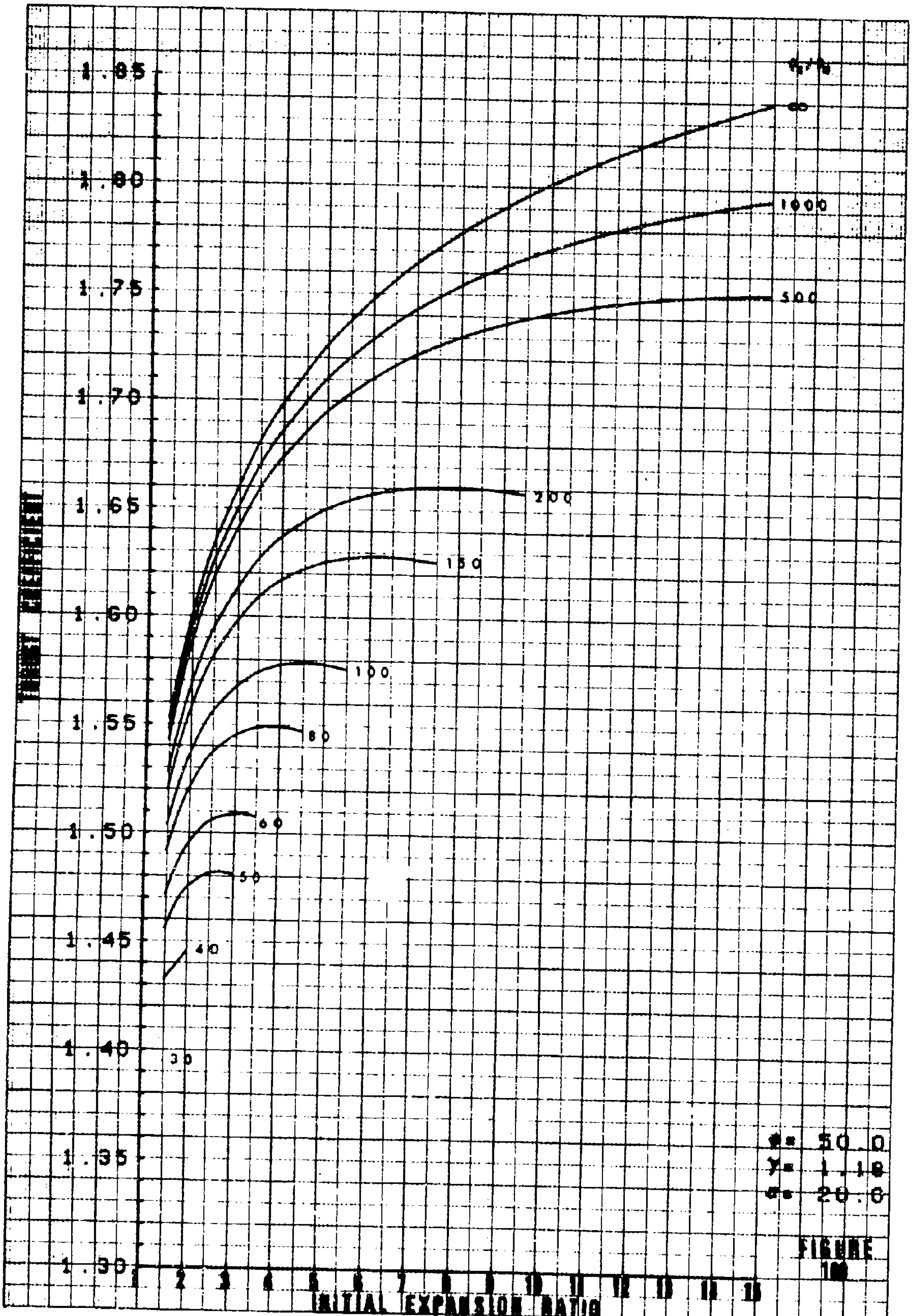

THRUST DEFLECTION ANGLE, DEGREES
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
-1.0
-2.0
-3.0
INITIAL EXPANSION RATIO
1000
500
200


2.00
1.50
1.00
.50
0
-.50
-1.00
-1.50
-2.00
-2.50
-3.00
∞
1000
500
400
300
200
150
100
80
60
50
40
30
20
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
INITIAL EXPANSION RATIO
FIGURE

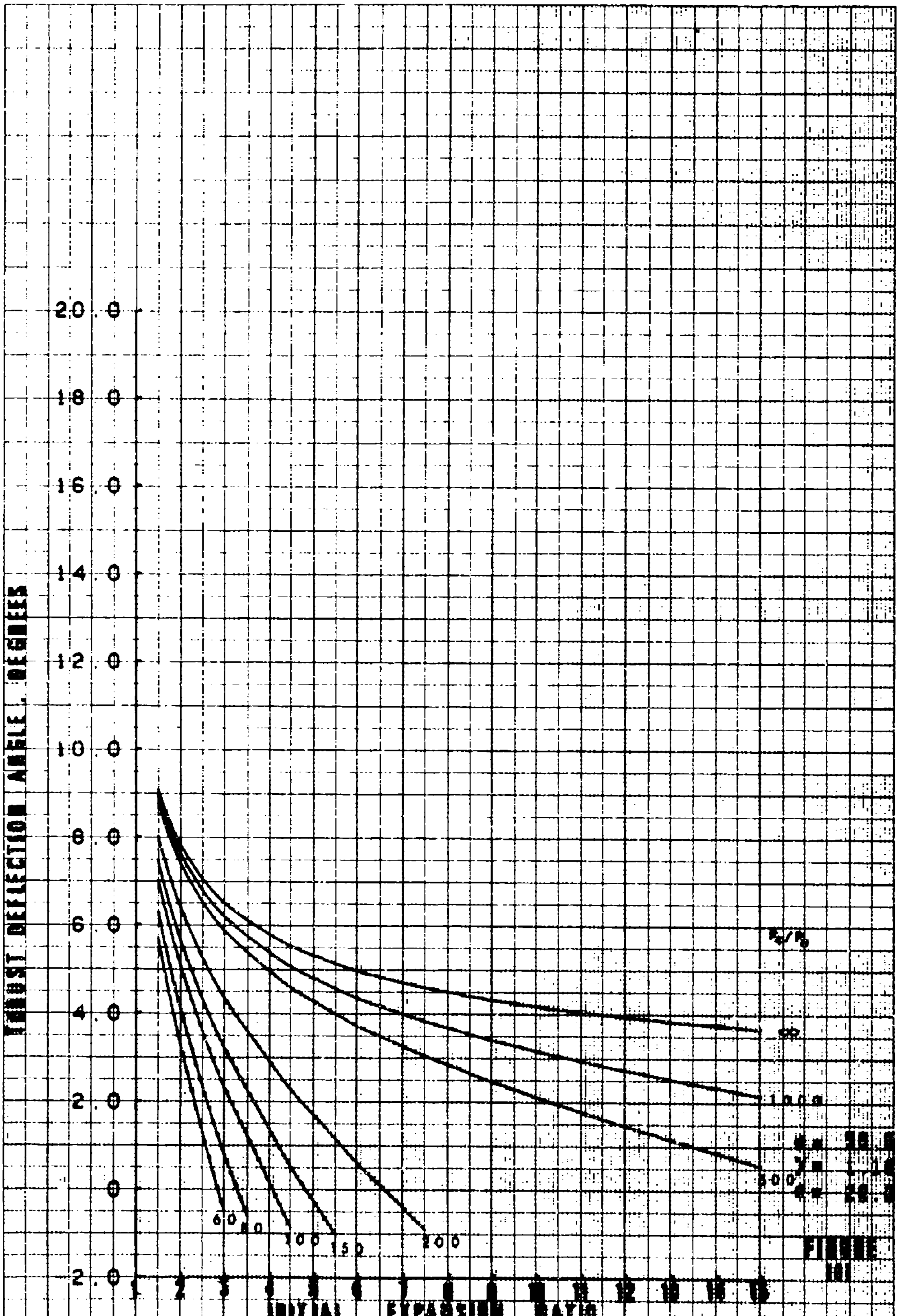

COEFFICIENT
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
INITIAL EXPANSION RATIO
∞
1000
500
200
150
100
80
60
50
40
30
20

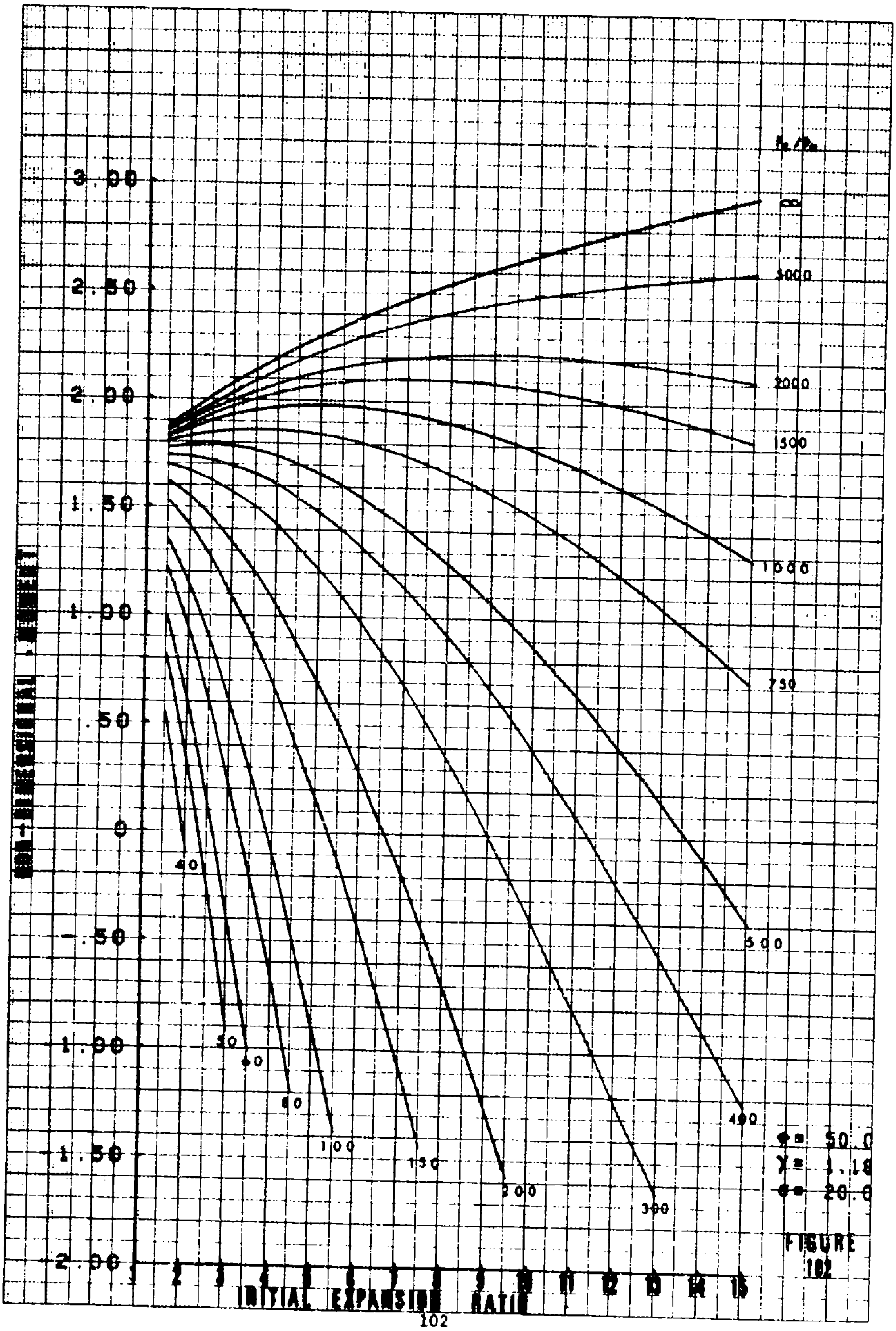

INITIAL EXPANSION RATIO
∞
1000
500
200
150
100
80
60
50
40
30


NON-DIMENSIONAL MOMENT
3.00
2.50
2.00
1.50
1.00
.50
0
-.50
-1.00
-1.50
-2.00
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
∞
2000
1000
750
500
400
300
200
150
100
80
60
50
40
30
FIGURE



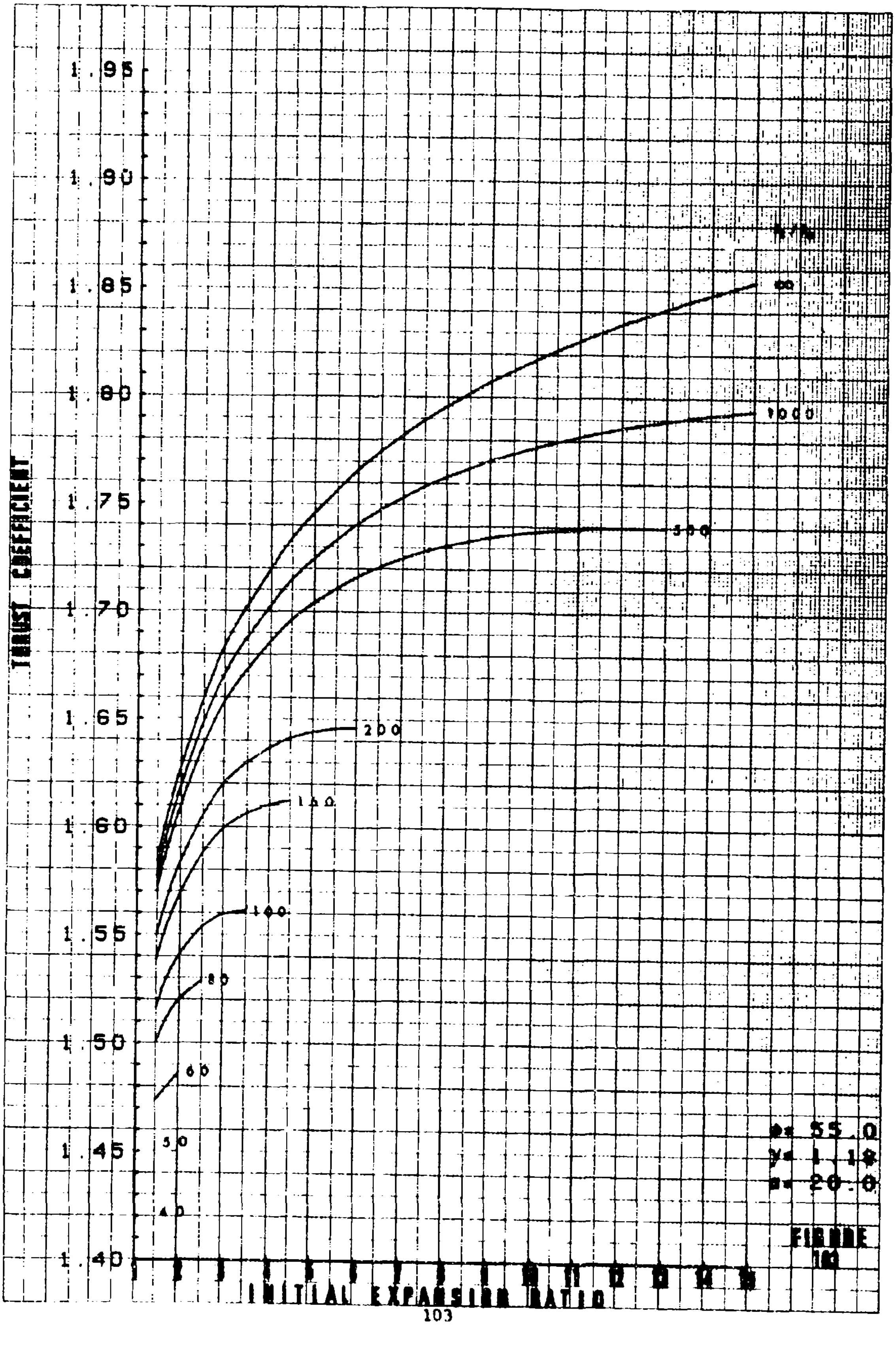
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
THRUST COEFFICIENT
INITIAL EXPANSION RATIO
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
∞
1000
500
200
150
100
80
60
50
40
30
50.0
1.18
20.0
FIGURE
10

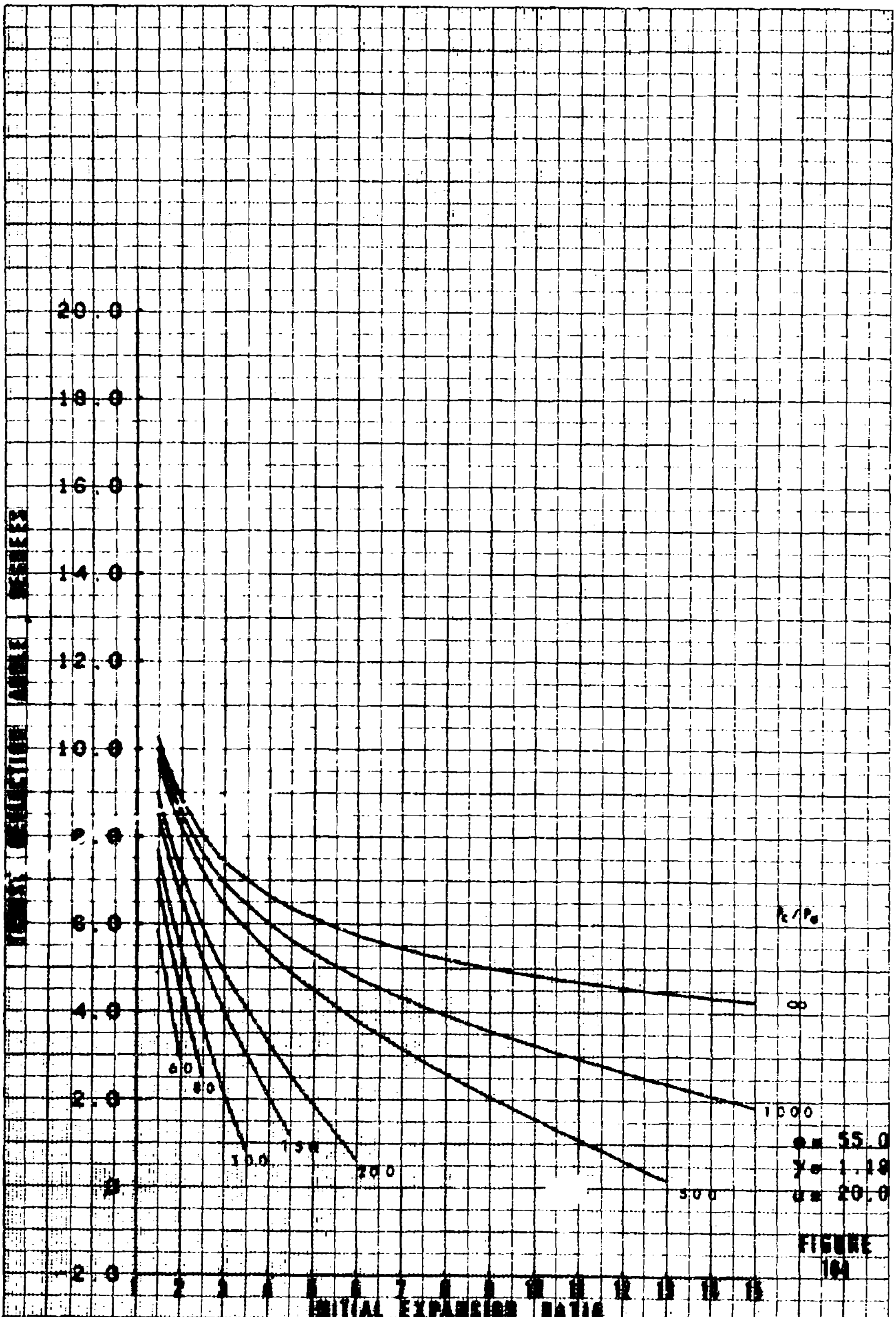

THRUST DEFLECTION ANGLE, DEGREES
20.0
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0
2.0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
INITIAL EXPANSION RATIO
60
80
100
150
200
500
1000
∞
FIGURE
101



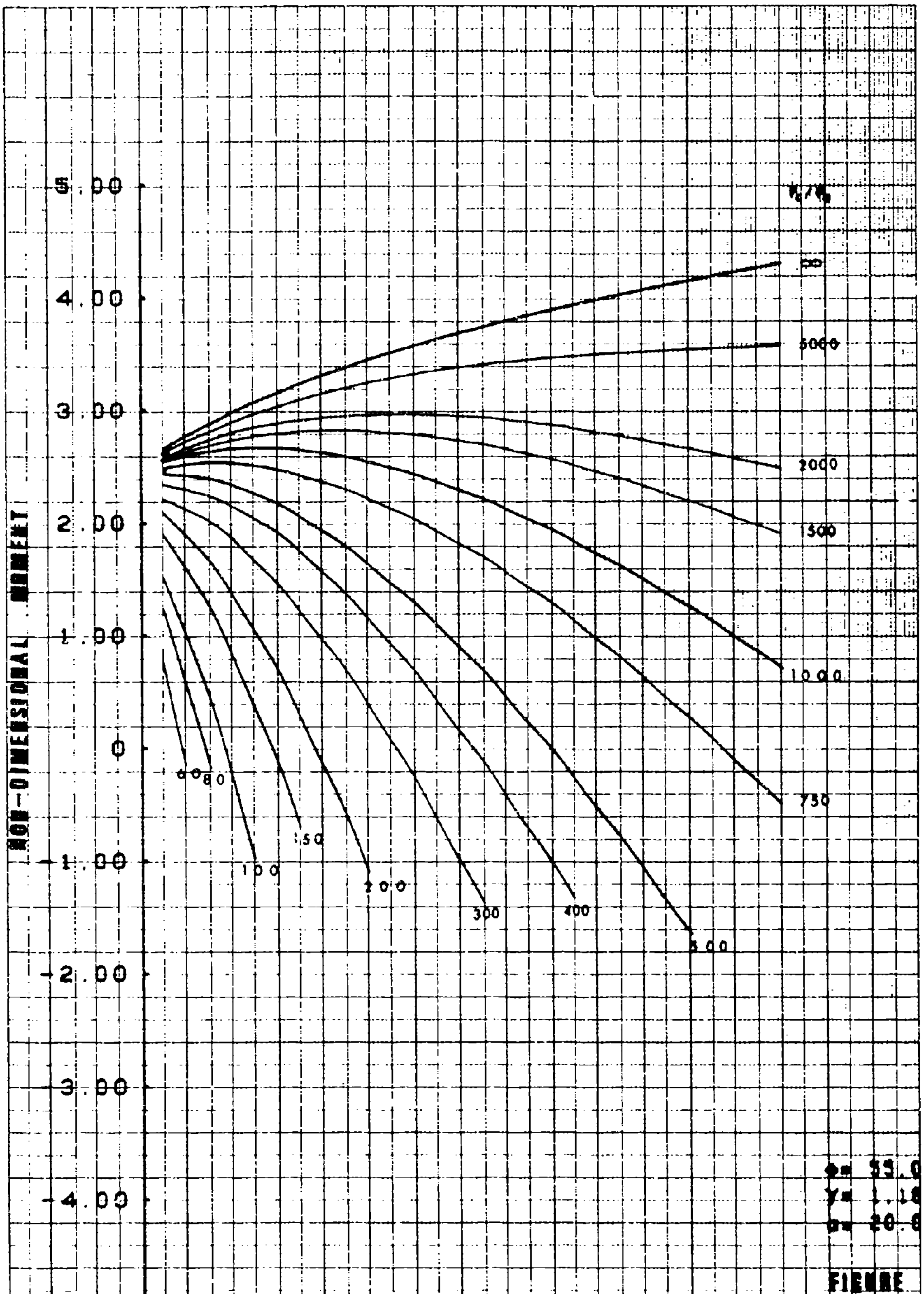
3.00
2.50
2.00
1.50
1.00
.50
0
-.50
-1.00
-1.50
-2.00
∞
3000
2000
1500
1000
750
500
400
300
200
150
100
80
60
50
40
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
INITIAL EXPANSION RATIO

FIGURE 102


THRUST COEFFICIENT
1.95
1.90
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
INITIAL EXPANSION RATIO
∞
1000
500
200
150
100
80
60
50
40



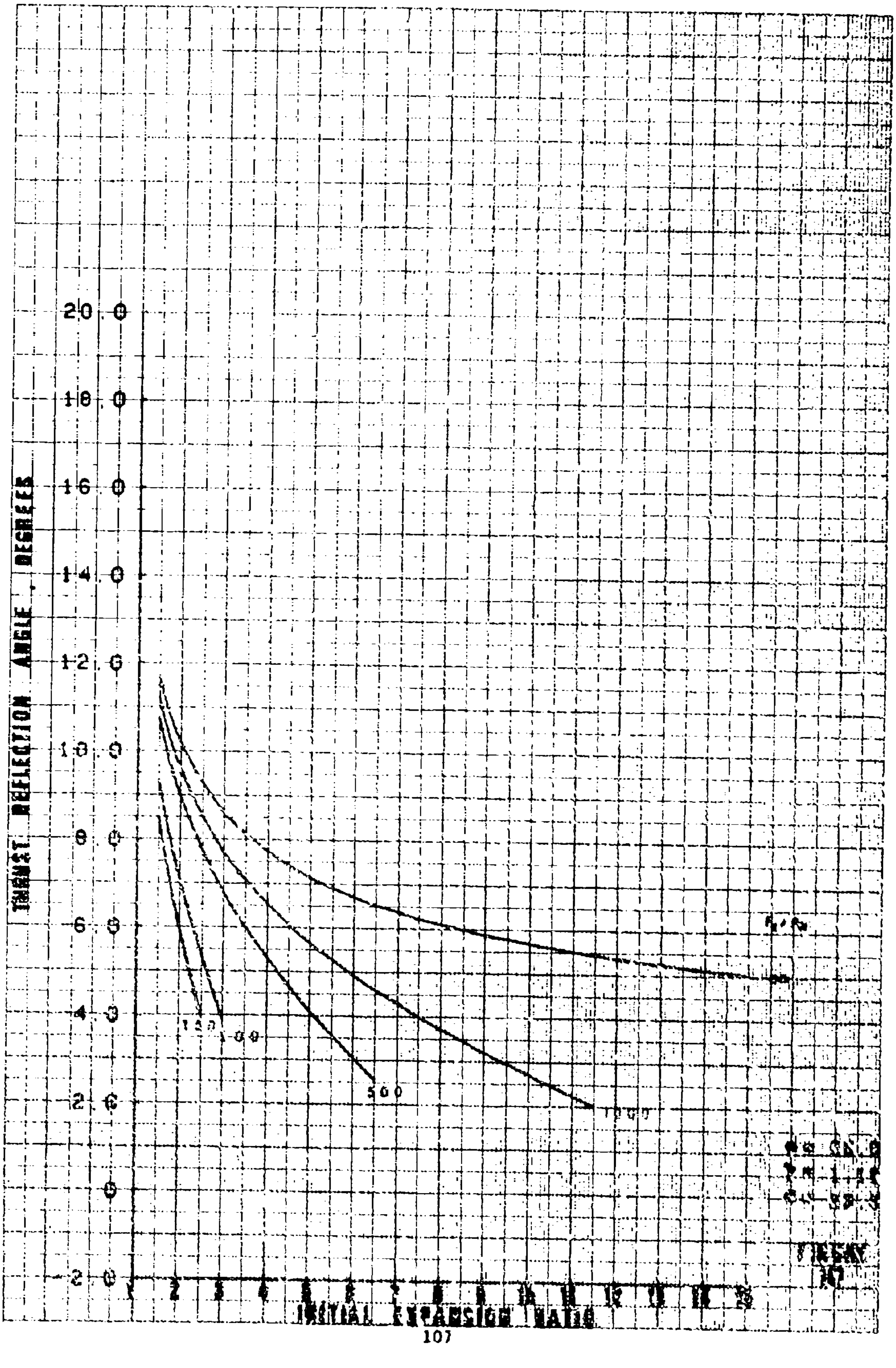
20.0
18.0
16.0
14.0
12.0
10.0
6.0
4.0
2.0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
P_c/P_e
∞
1000
500
200
150
100
80
60
= 55.0
= 20.0
FIGURE



5.00
4.00
3.00
2.00
1.00
0
-1.00
-2.00
-3.00
-4.00
-5.00
NON-DIMENSIONAL MOMENT
INITIAL EXPANSION RATIO
2
3
4
5
6
7
8
9
10
11
12
13
14
15
5000
2000
1500
1000
750
60
80
100
150
200
300
400
500

FIGURE 105


1.95
1.90
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1000
500
200
150
100
2
3
4
5
6
7
8
9
10
11
12
13
14
15
INITIAL EXPANSION RATIO
FIGURE


THRUST DEFLECTION ANGLE, DEGREES
20.0
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0
-2.0
500
1000
INITIAL EXPANSION RATIO

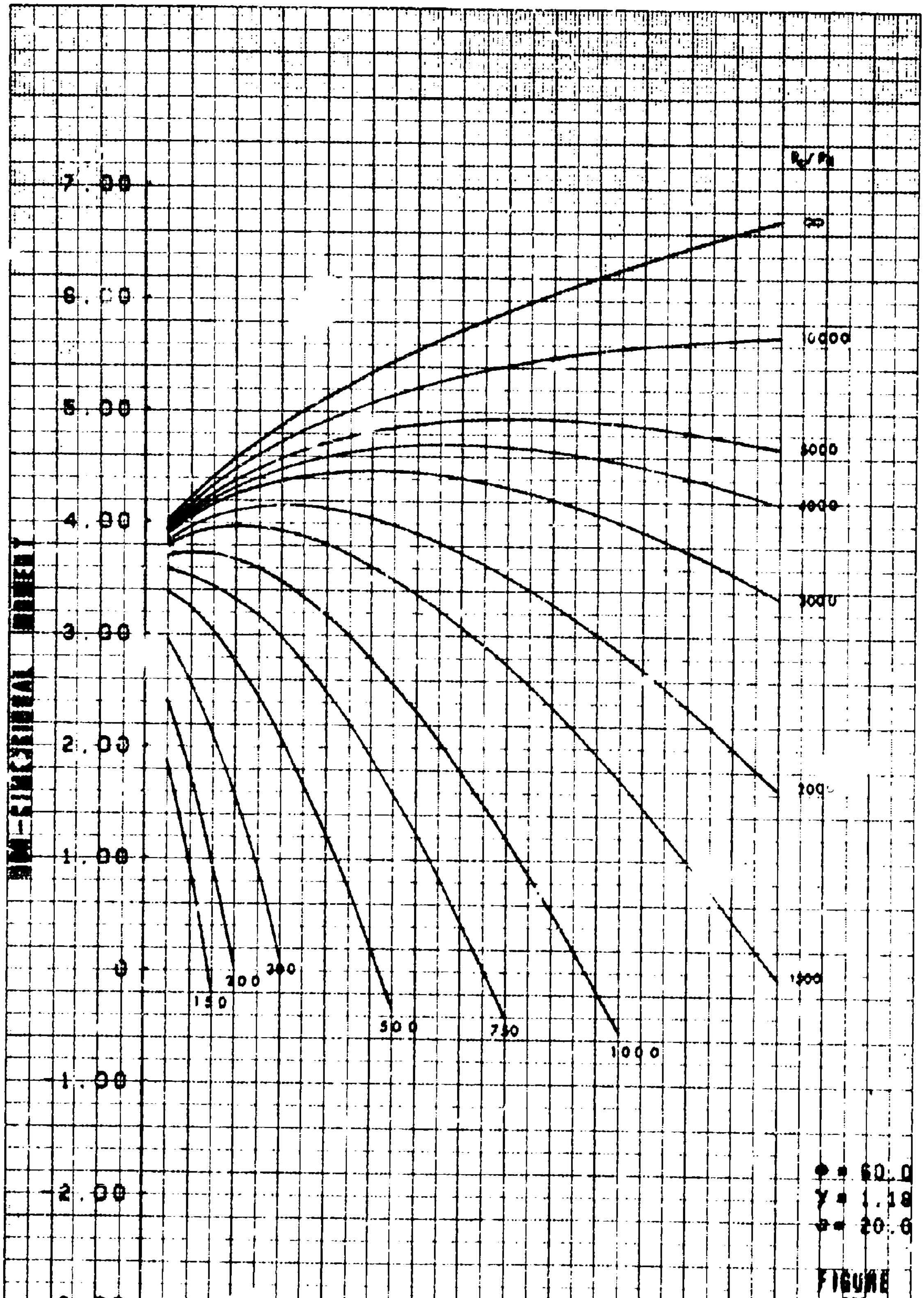
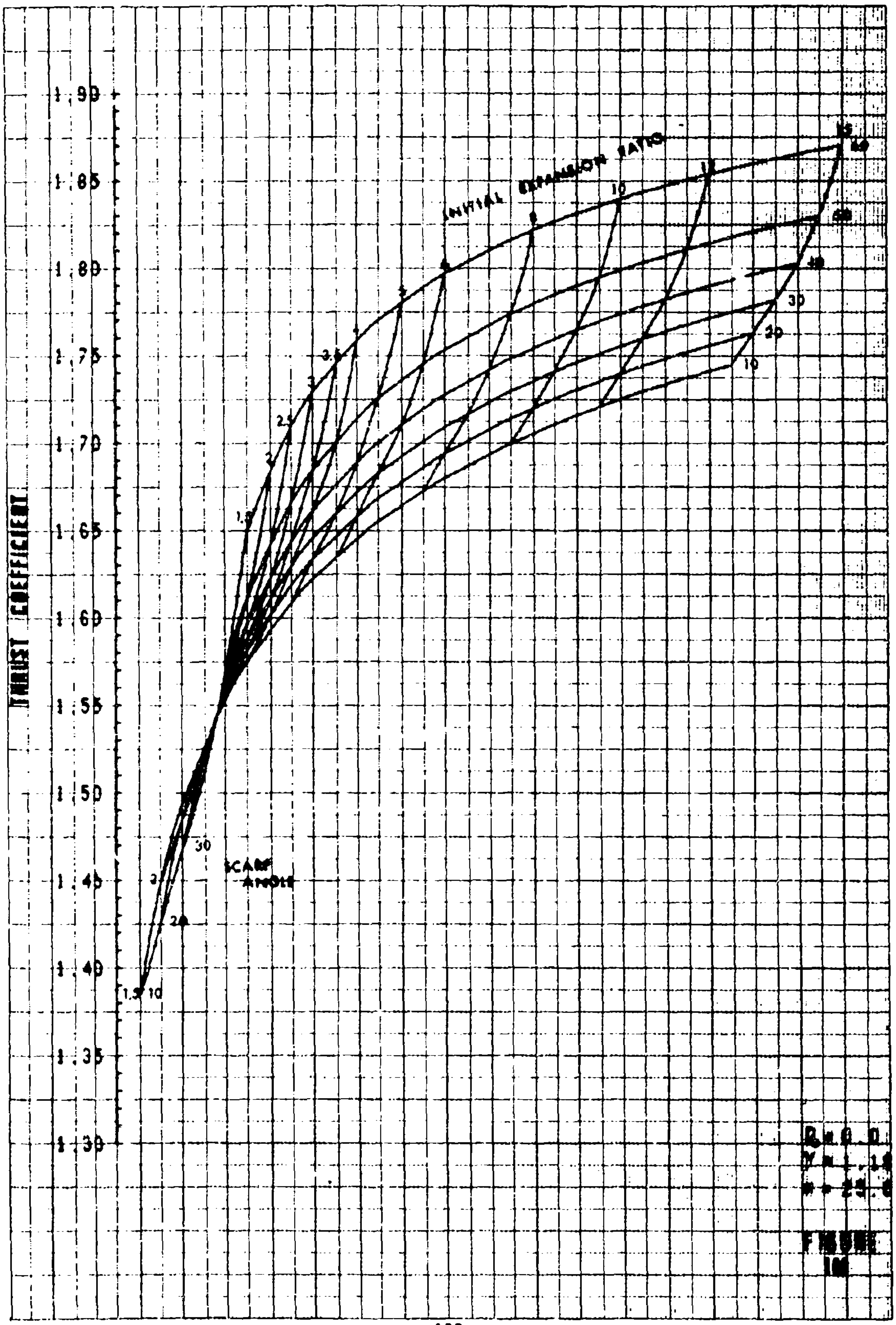
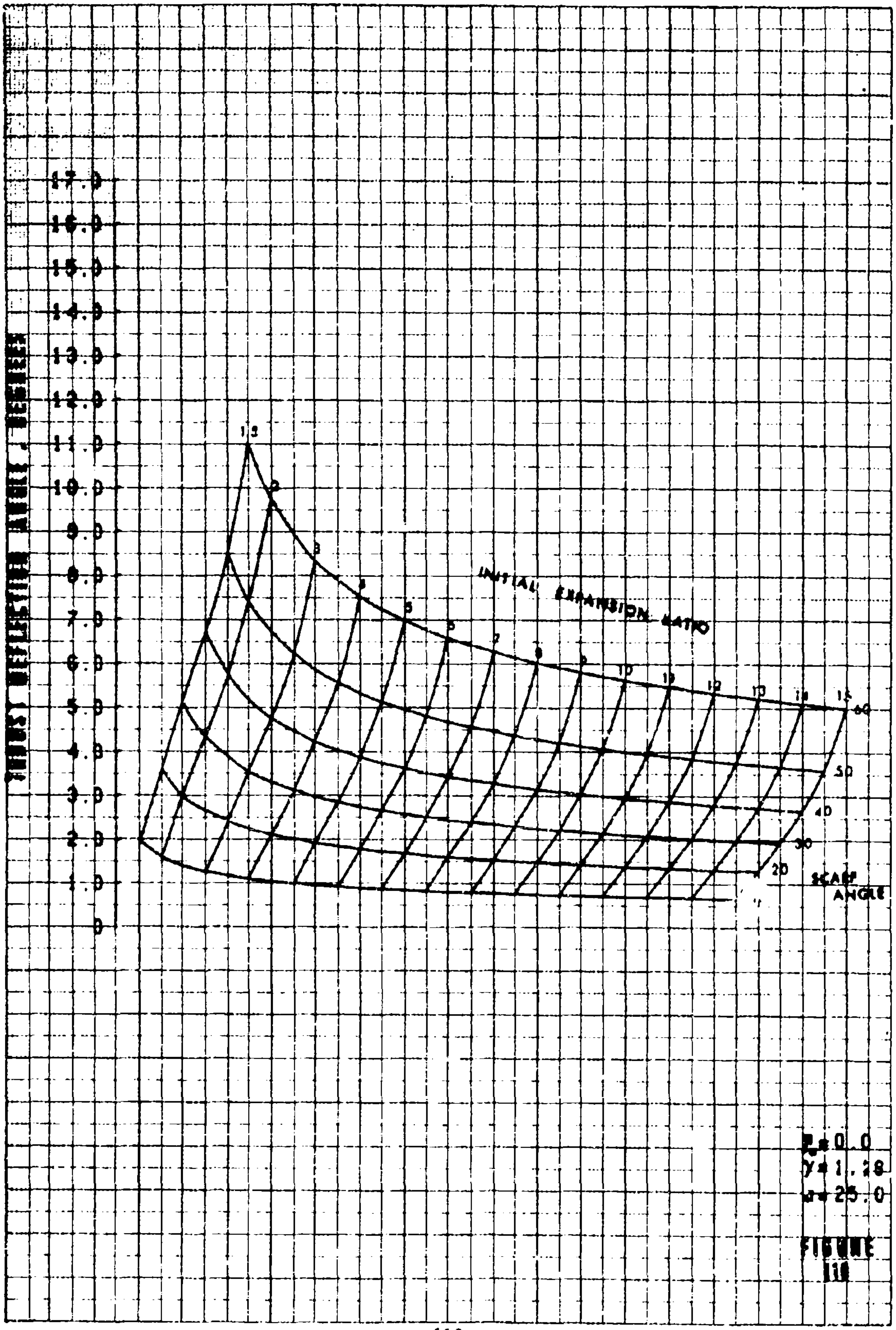

NON-DIMENSIONAL MOMENT
INITIAL EXPANSION RATIO
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0
-1.00
-2.00
-3.00
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
∞
10000
5000
4000
3000
2000
1500
1000
750
500
300
200
150
Φ = 60.0
γ = 1.18
θ = 20.6

FIGURE 1M



THRUST COEFFICIENT
1.90
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
INITIAL EXPANSION RATIO
SCARF ANGLE
1.5
2
2.5
3
3.5
4
5
6
8
10
15
10
20
30
40
50
60


THRUST DEFLECTION ANGLE, DEGREES
17.0
16.0
15.0
14.0
13.0
12.0
11.0
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
INITIAL EXPANSION RATIO
SCARF ANGLE
60
50
40
30
20
$P_a = 0.0$
$\gamma = 1.28$
$\alpha = 25.0$
FIGURE

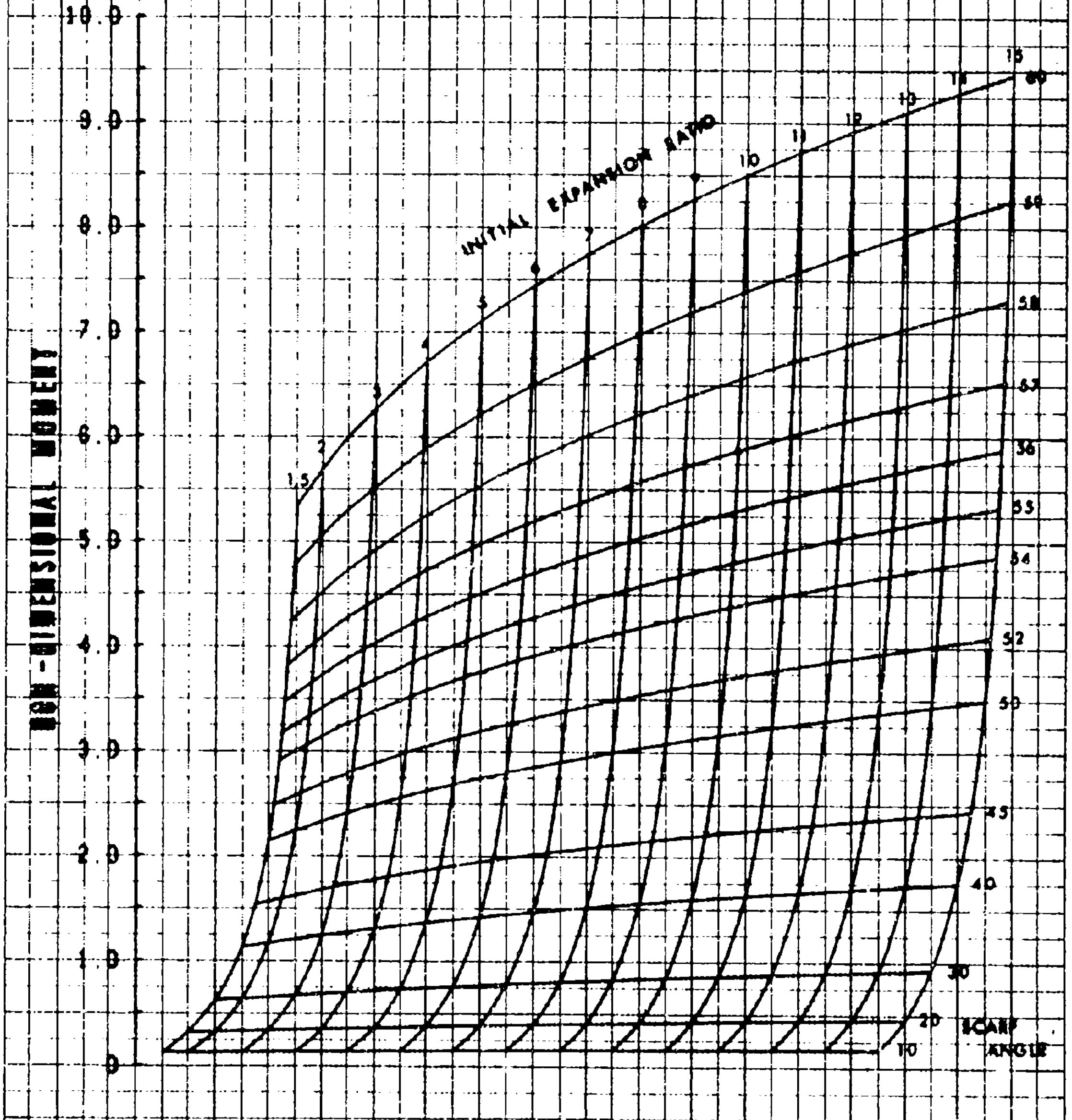
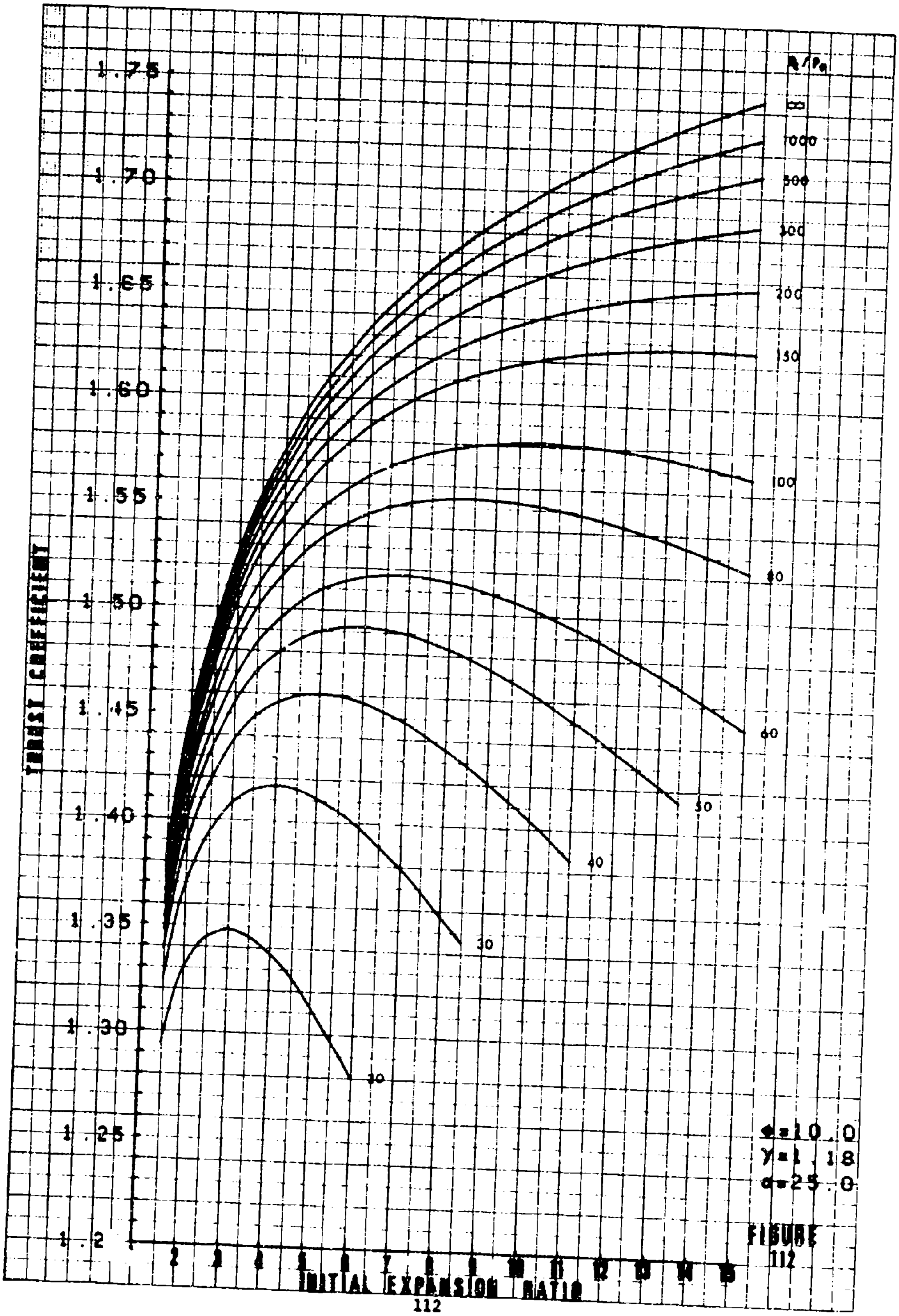

NON-DIMENSIONAL MOMENT
INITIAL EXPANSION RATIO
SCARF ANGLE
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
P_a = 0.0
γ = 1.18
θ = 25.0

FIGURE 111



THRUST COEFFICIENT
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
1.25
1.2
INITIAL EXPANSION RATIO
2
3
4
5
6
7
8
9
10
11
12
13
14
15
P_c/P_a
∞
1000
500
300
200
150
100
80
60
50
40
30
20
ϕ=10.0
γ=1.18
α=25.0

FIGURE 112

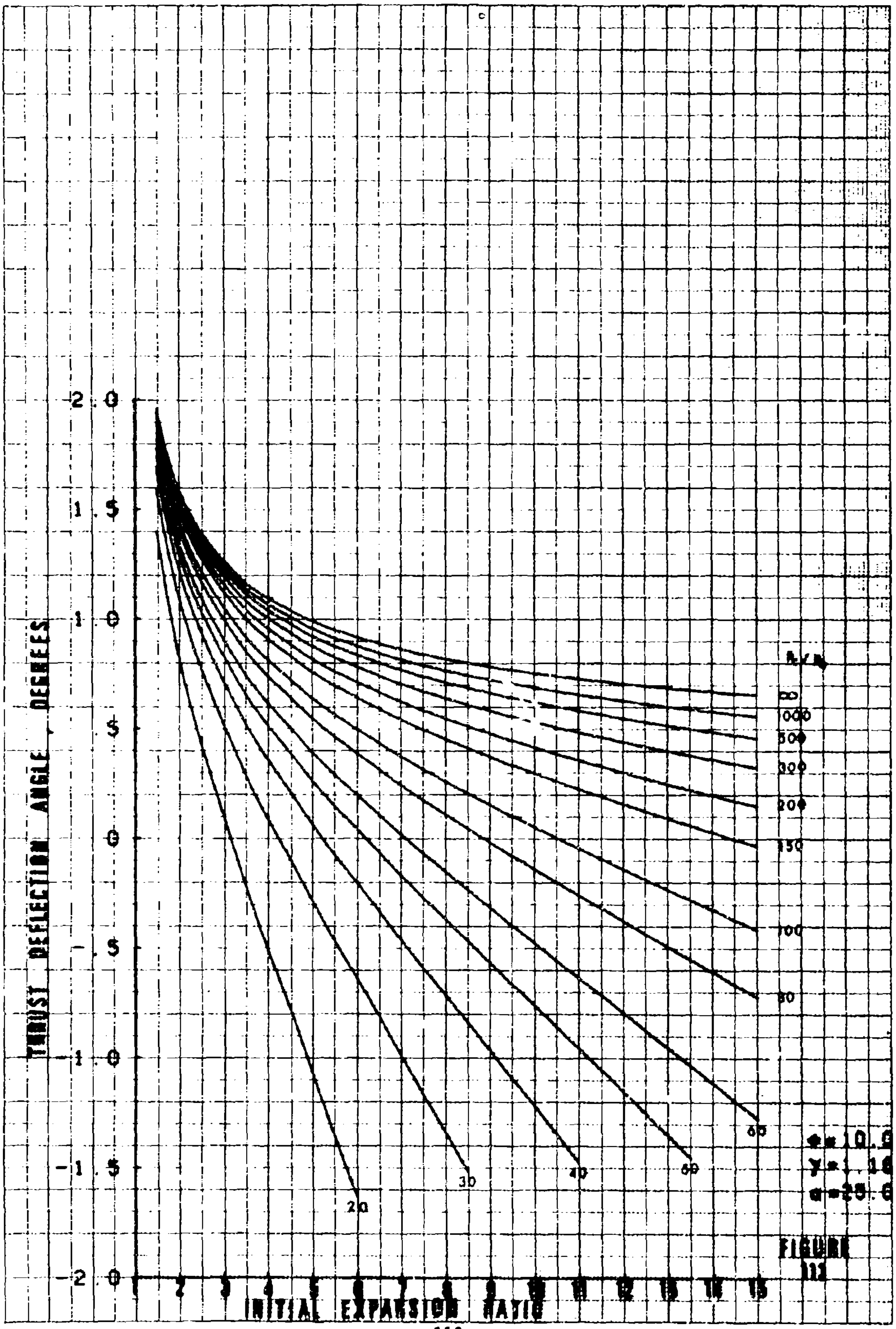
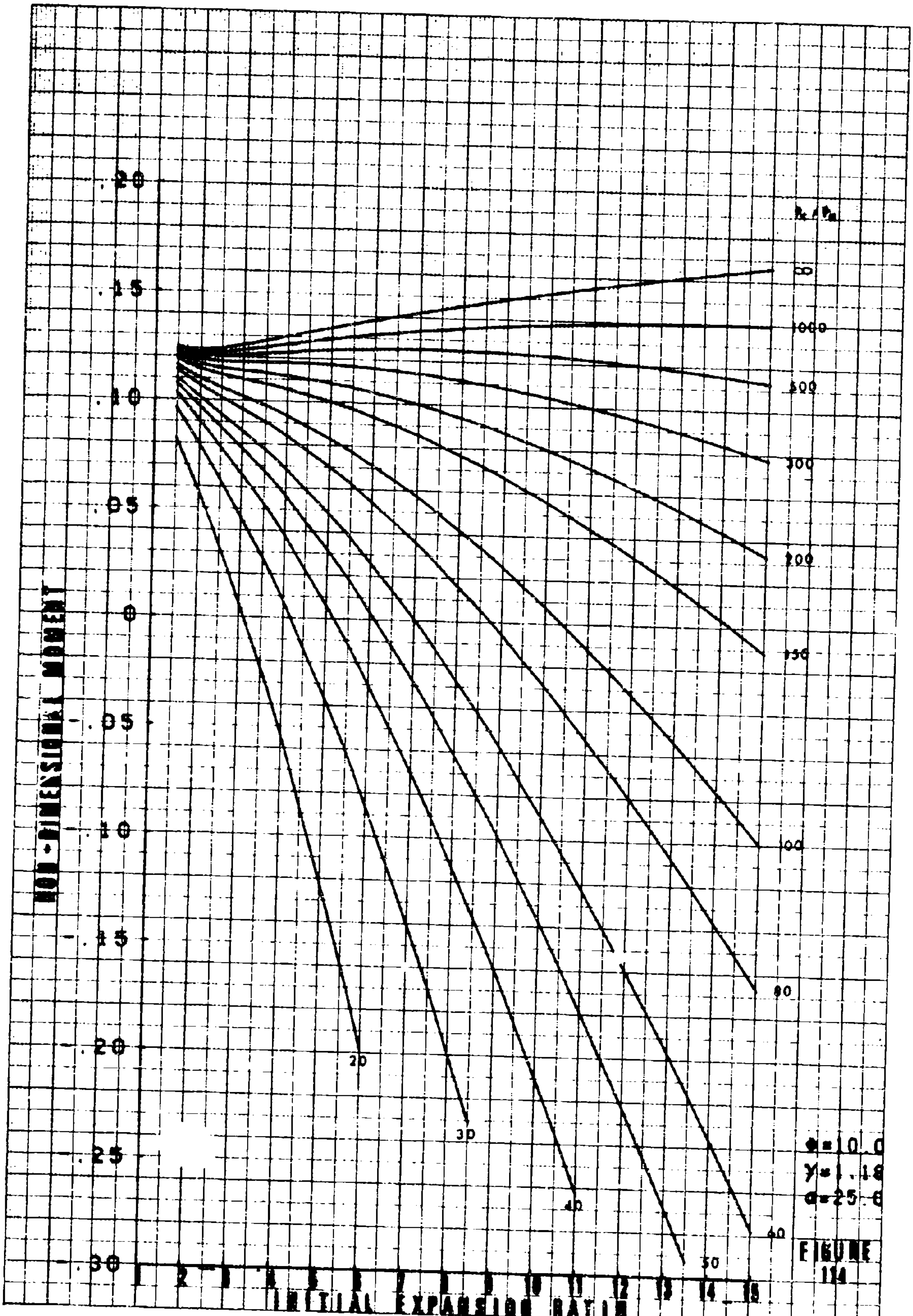
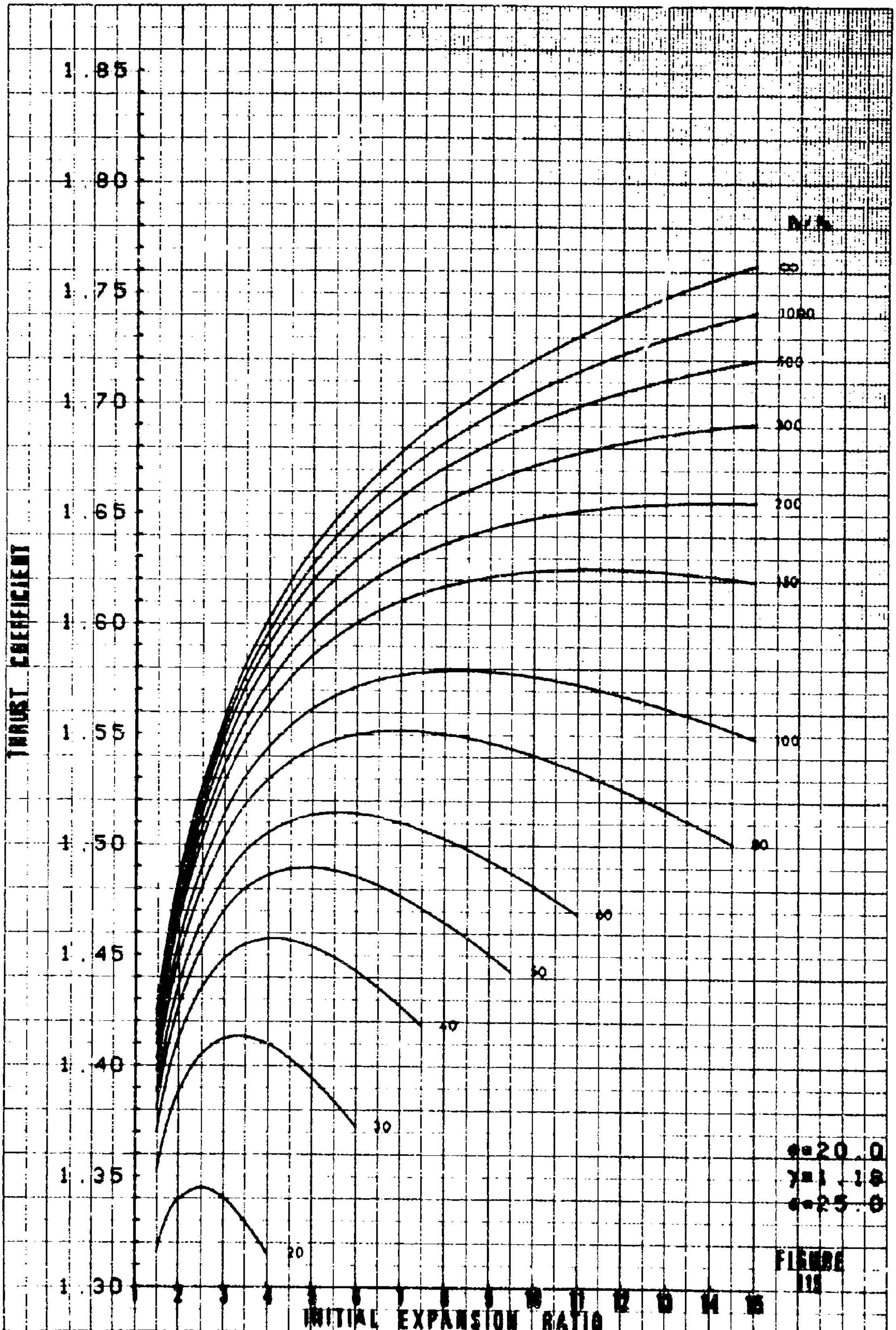

THRUST DEFLECTION ANGLE, DEGREES
2.0
1.5
1.0
.5
0
-.5
-1.0
-1.5
-2.0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
INITIAL EXPANSION RATIO
∞
1000
500
300
200
150
100
80
60
50
40
30
20

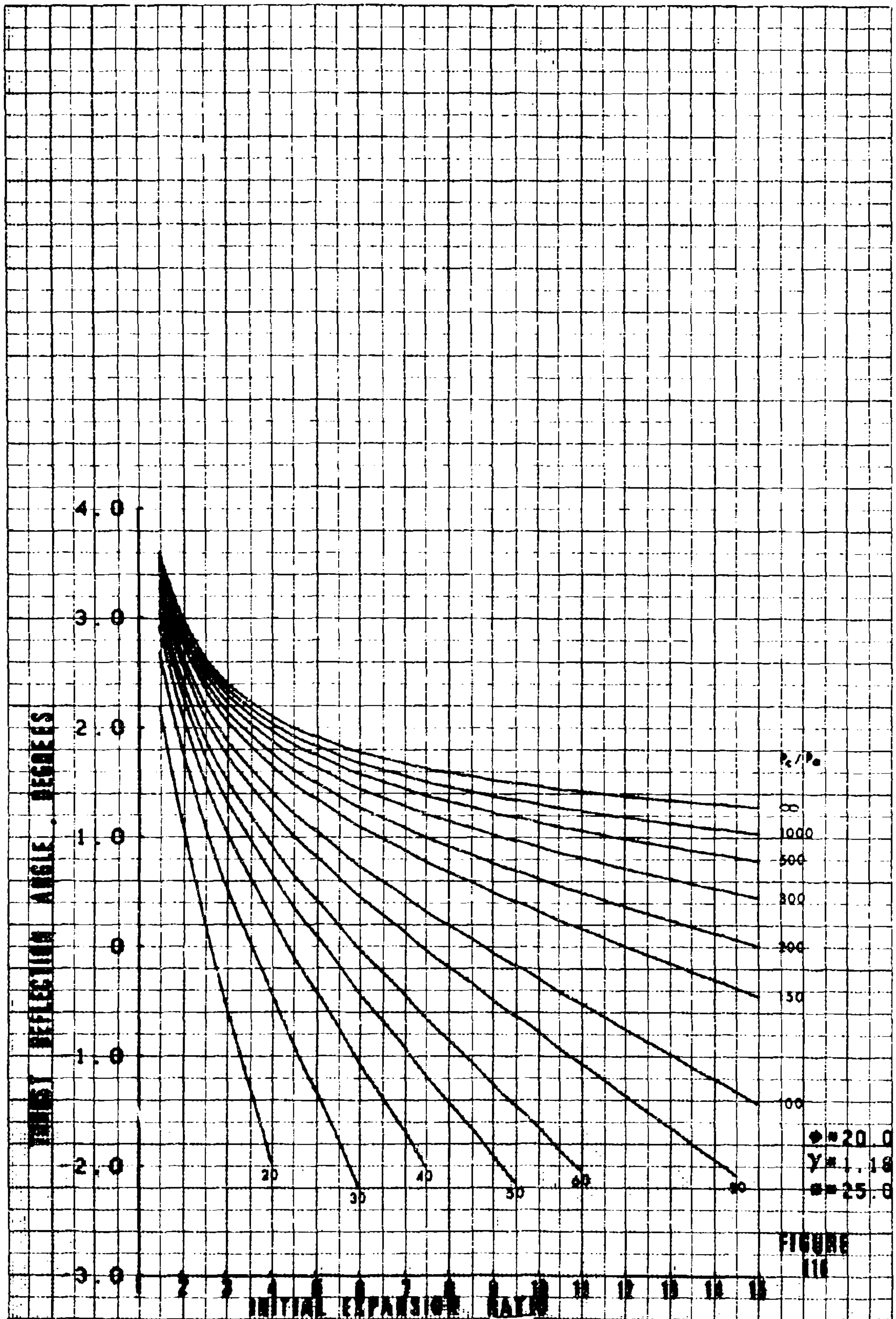
FIGURE 111

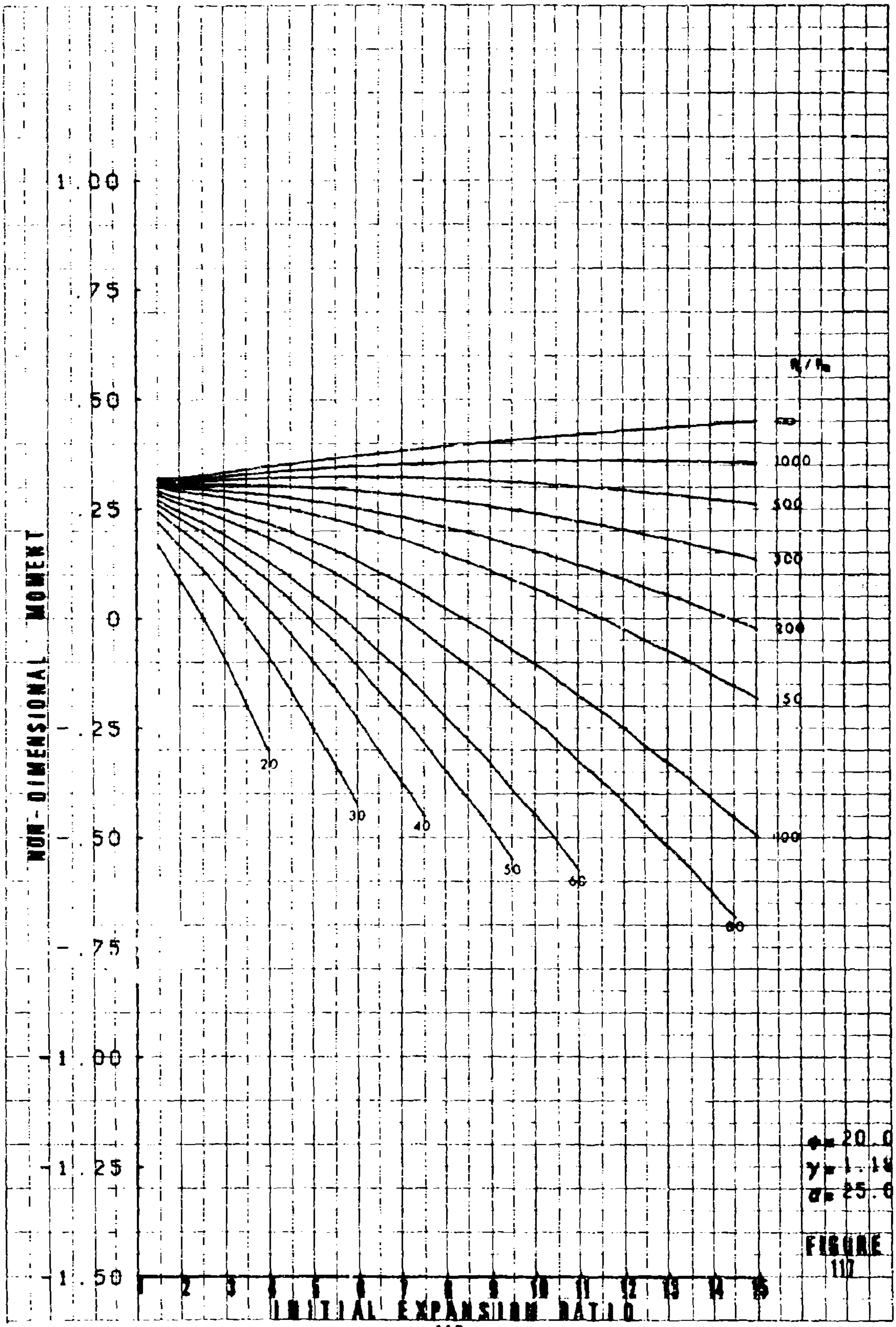


NON-DIMENSIONAL MOMENT
INITIAL EXPANSION RATIO
.20
.15
.10
.05
0
-.05
-.10
-.15
-.20
-.25
-.30
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
∞
1000
500
300
200
150
100
80
60
50
40
30
20
Φ=10.0
γ=1.18
α=25.6

FIGURE 114


THRUST COEFFICIENT
INITIAL EXPANSION RATIO
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
2
3
4
5
6
7
8
9
10
11
12
13
14
15
∞
1000
500
300
200
150
100
80
60
50
40
30
20
FIGURE
115


THRUST DEFLECTION ANGLE, DEGREES
4.0
3.0
2.0
1.0
0
-1.0
-2.0
-3.0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
INITIAL EXPANSION RATIO
P_c/P_a
∞
1000
500
300
200
150
100
20
30
40
50
60
80
Φ=20.0
γ=1.18
θ=25.0
FIGURE 116



NON-DIMENSIONAL MOMENT
INITIAL EXPANSION RATIO
1.00
.75
.50
.25
0
-.25
-.50
-.75
-1.00
-1.25
-1.50
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
1000
500
300
200
150
100
80
60
50
40
30
20

FIGURE 117

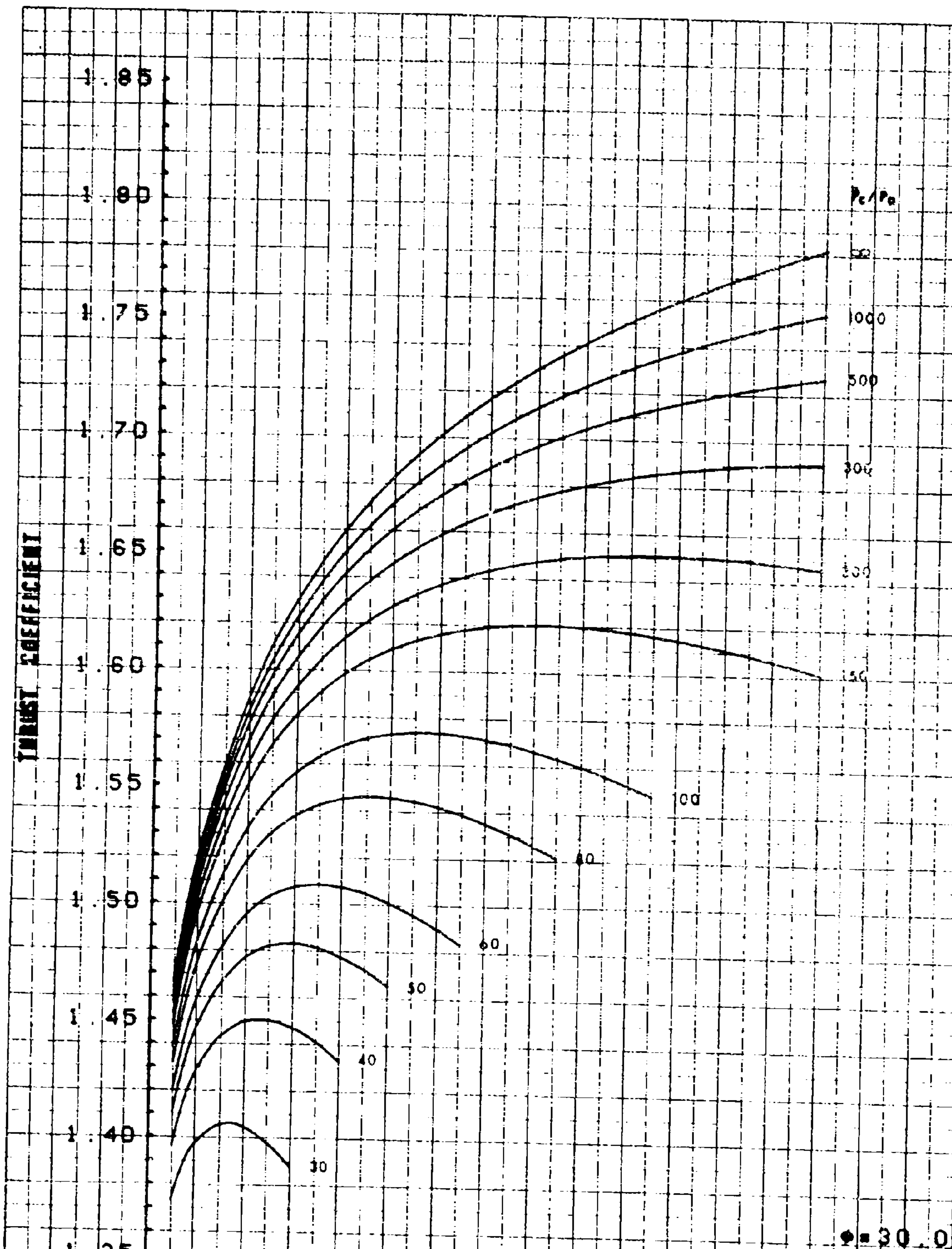

THRUST COEFFICIENT
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
INITIAL EXPANSION RATIO
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
P_c/P_a
1000
500
300
100
80
60
50
40
30
20
Φ = 30.0
γ = 1.18
α = 25.0

FIGURE 118

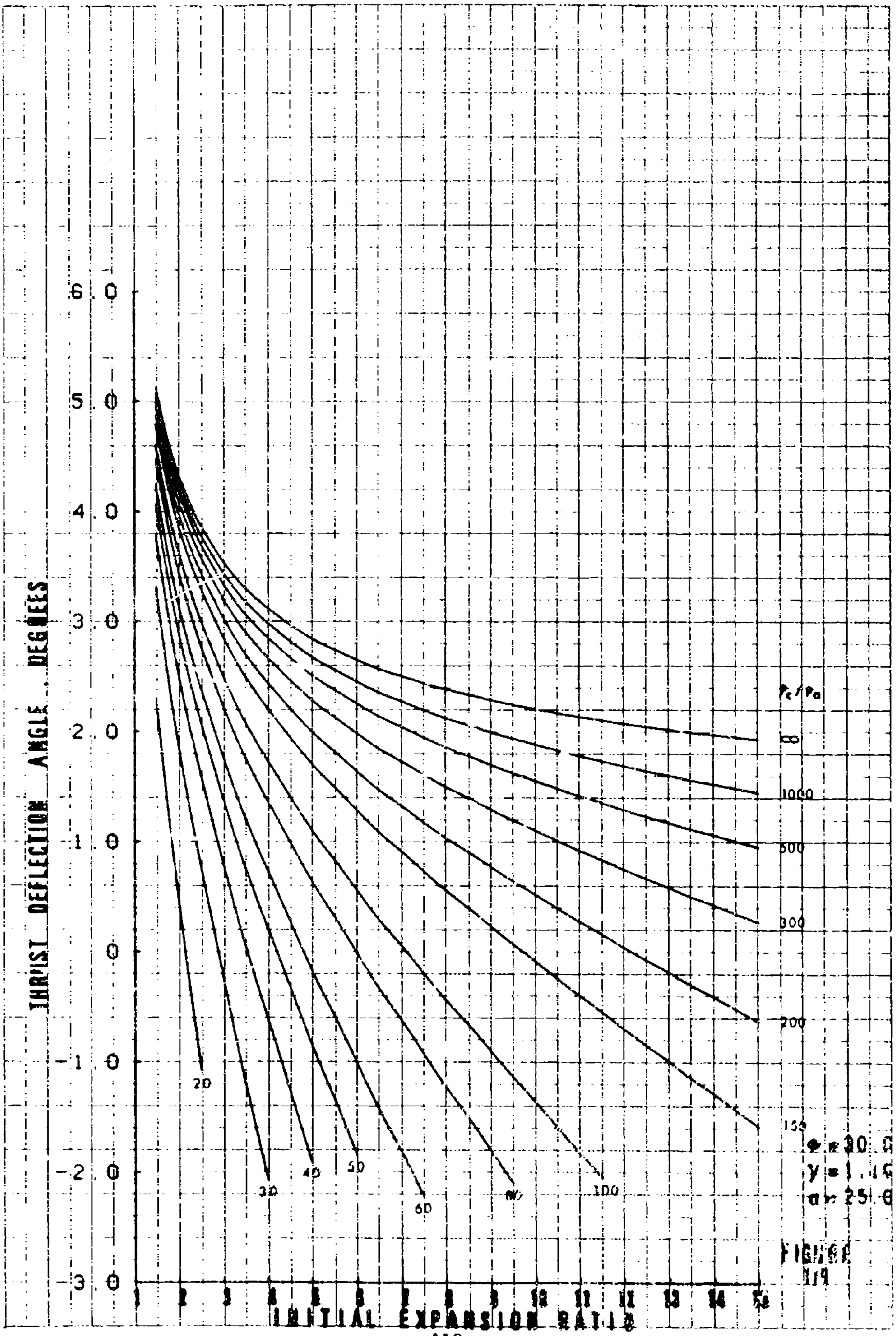
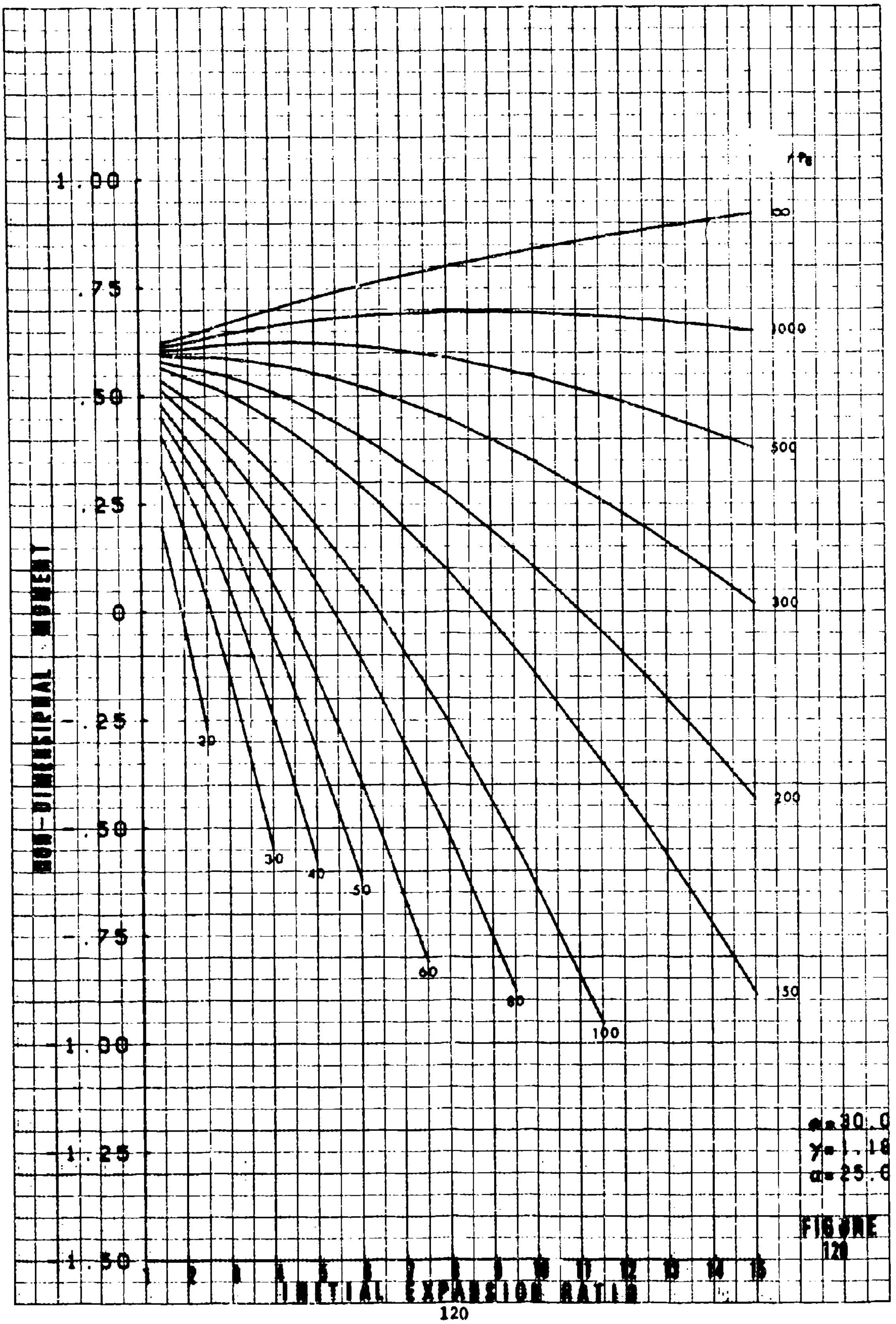
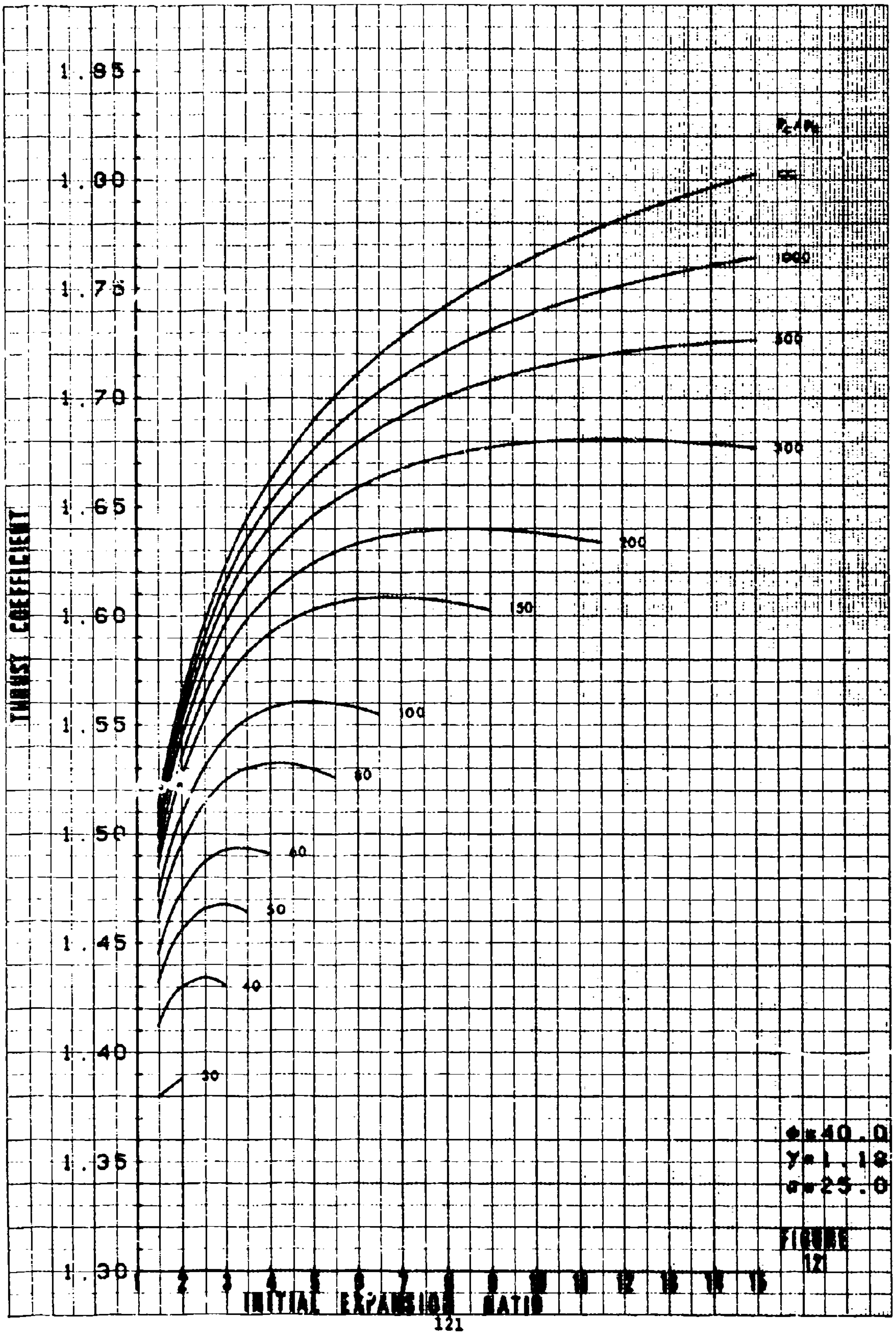
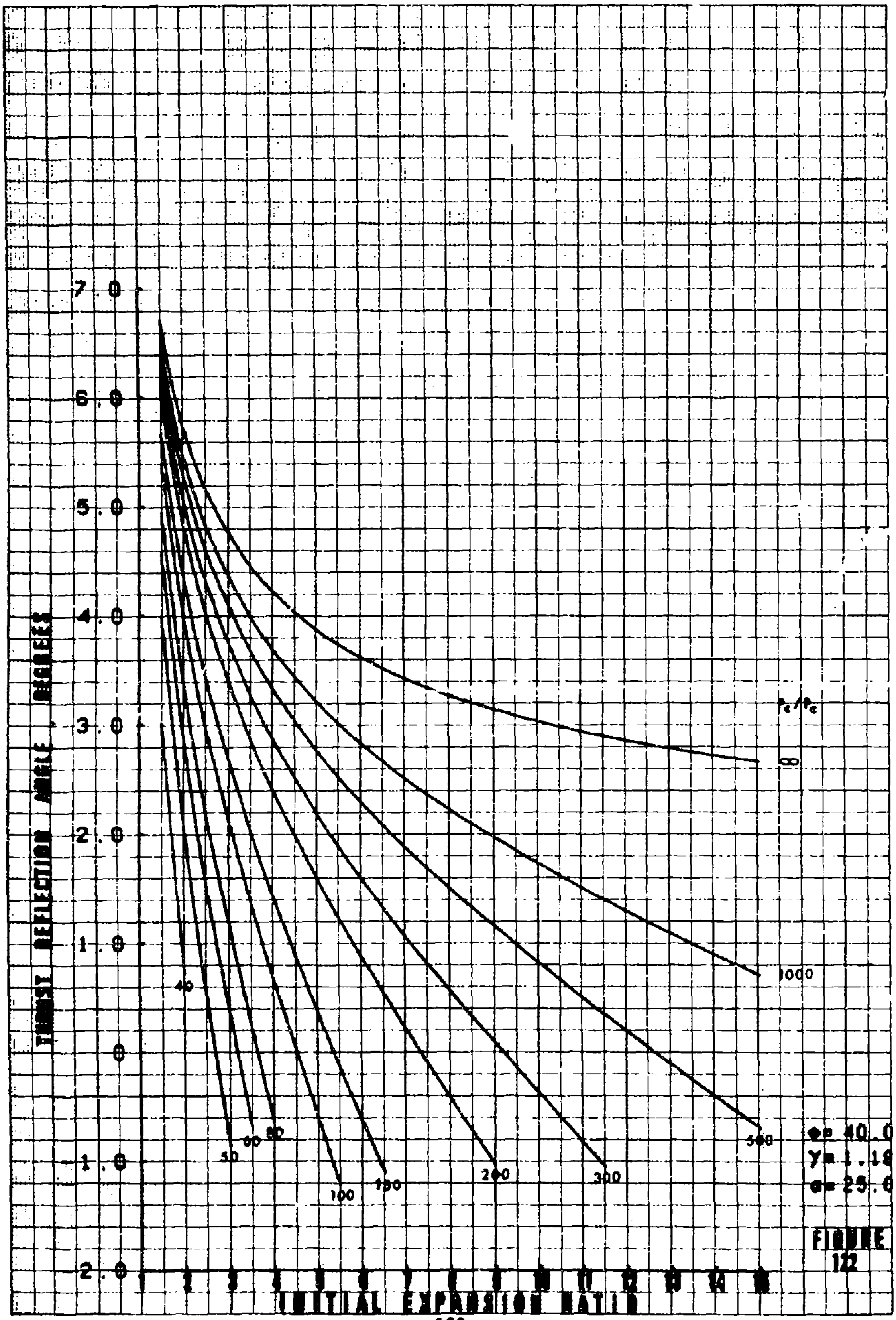
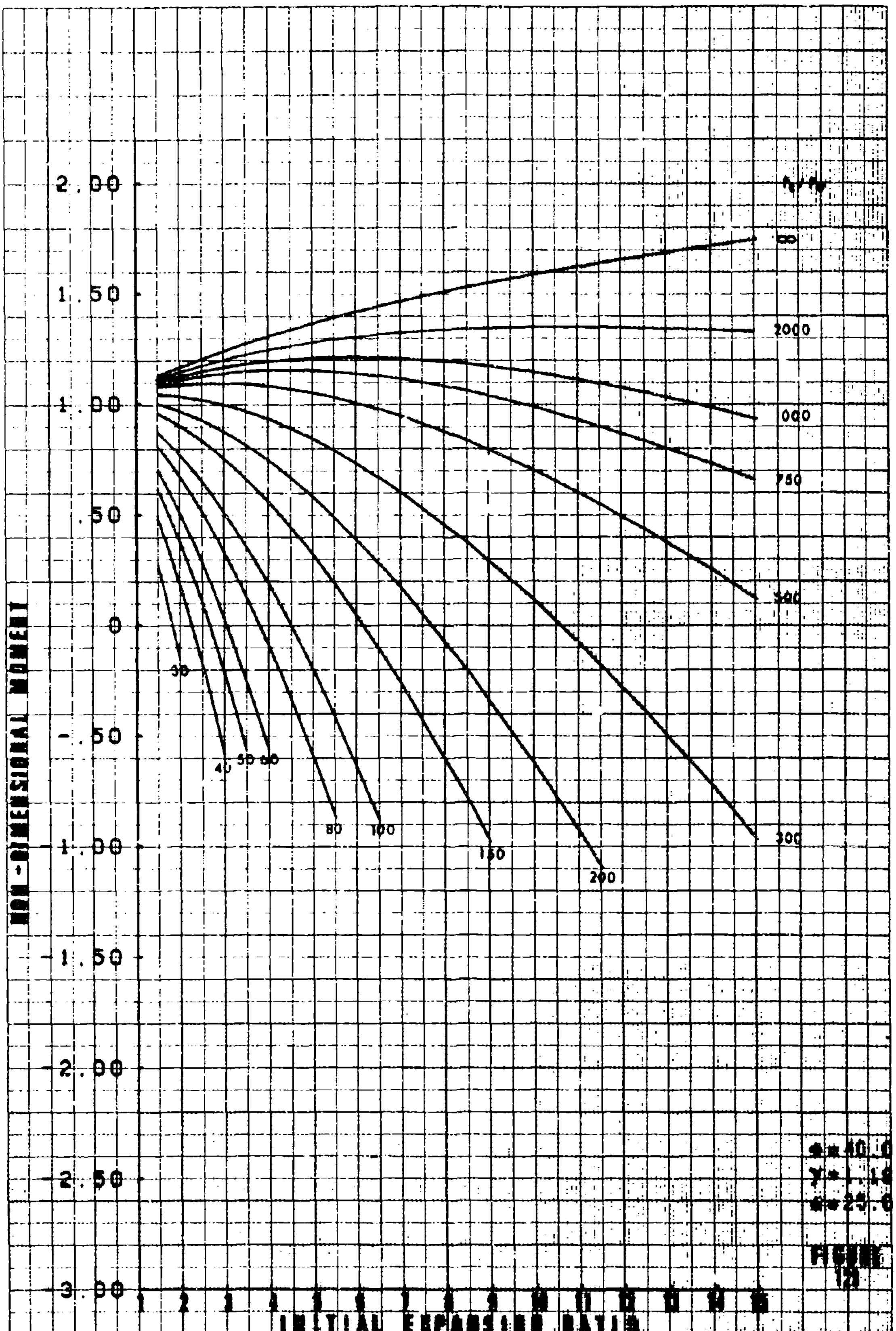

THRUST DEFLECTION ANGLE, DEGREES
6.0
5.0
4.0
3.0
2.0
1.0
0
-1.0
-2.0
-3.0
INITIAL EXPANSION RATIO
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
P_c/P_a
∞
1000
500
300
200
150
100
80
60
50
40
30
20
ϕ = 30.0
γ = 1.10
α = 25.0

FIGURE 119


NON-DIMENSIONAL MOMENT
INITIAL EXPANSION RATIO
1.00
.75
.50
.25
0
-.25
-.50
-.75
-1.00
-1.25
-1.50
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
P_s
∞
1000
500
300
200
150
100
80
60
50
40
30
20
FIGURE 120


THRUST COEFFICIENT
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
1000
500
300
200
150
100
80
60
50
40
30
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
INITIAL EXPANSION RATIO
γ=1.18
FIGURE 121


THRUST DEFLECTION ANGLE, DEGREES
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
-1.0
-2.0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
INITIAL EXPANSION RATIO
40
50
60
80
100
150
200
300
500
1000
P_c/P_e
∞
FIGURE
122


NON-DIMENSIONAL MOMENT
2.00
1.50
1.00
.50
0
-.50
-1.00
-1.50
-2.00
-2.50
-3.00
INITIAL EXPANSION RATIO
∞
2000
1000
750
500
300
200
150
100
80
60
50
40
30
FIGURE

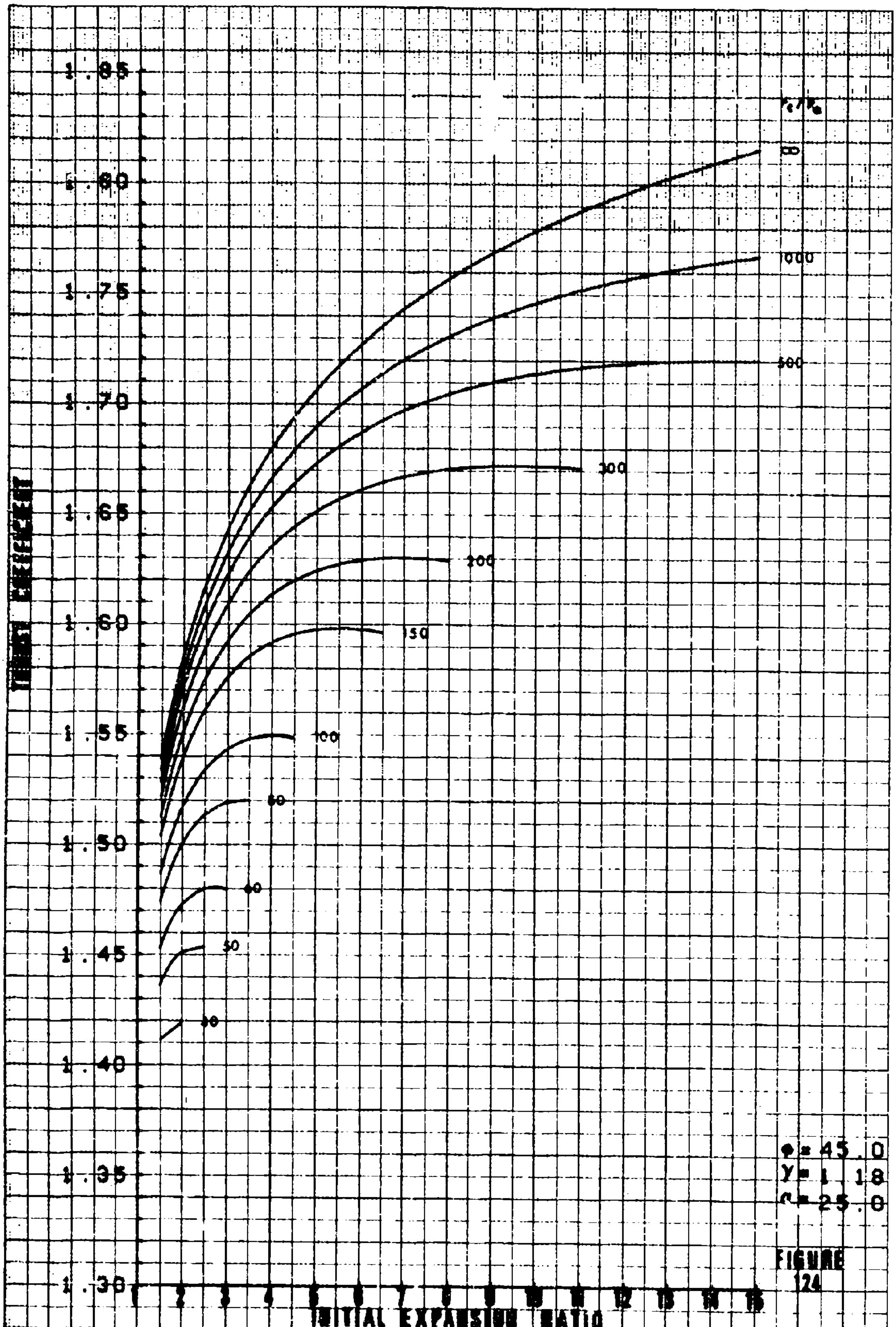
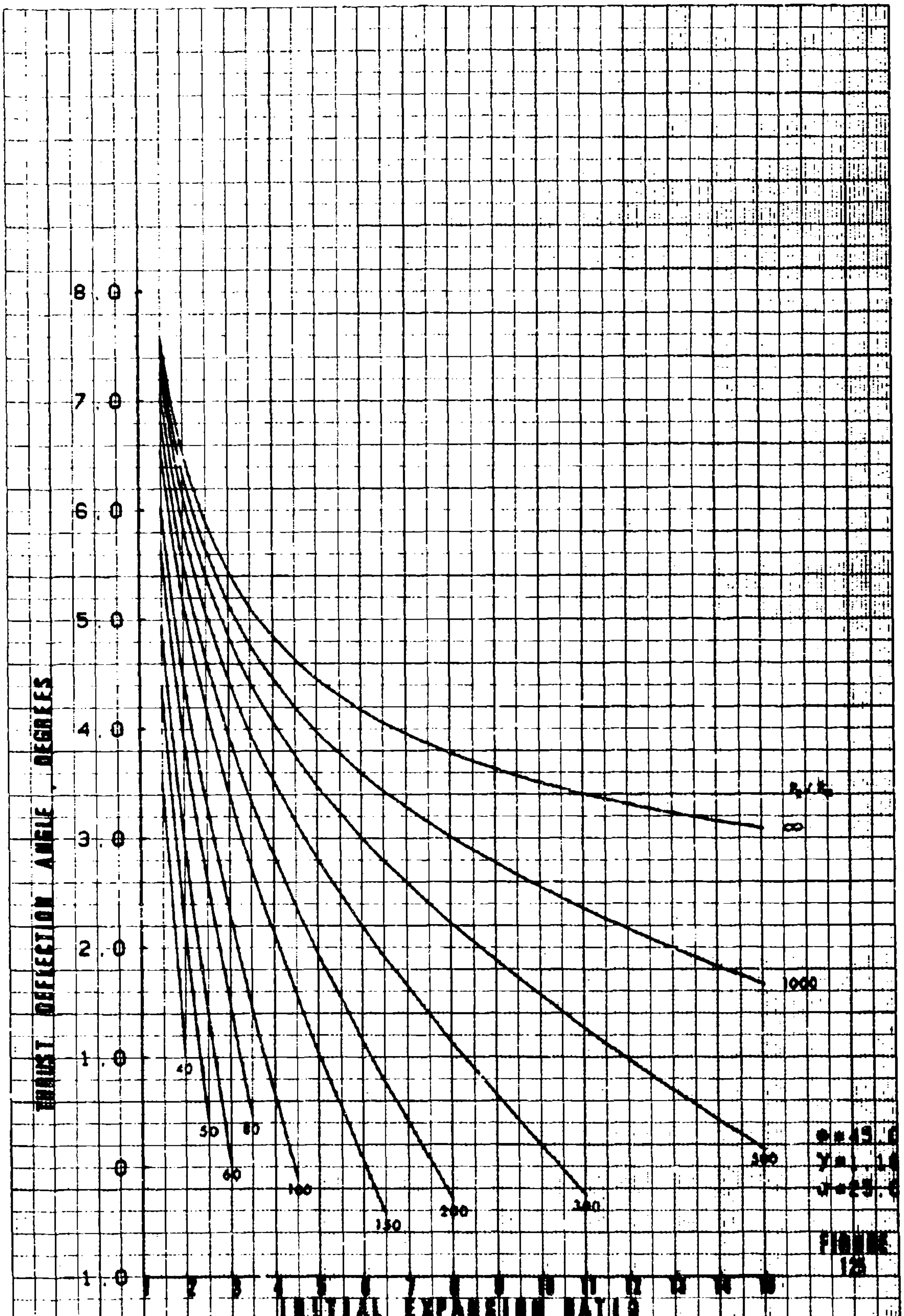
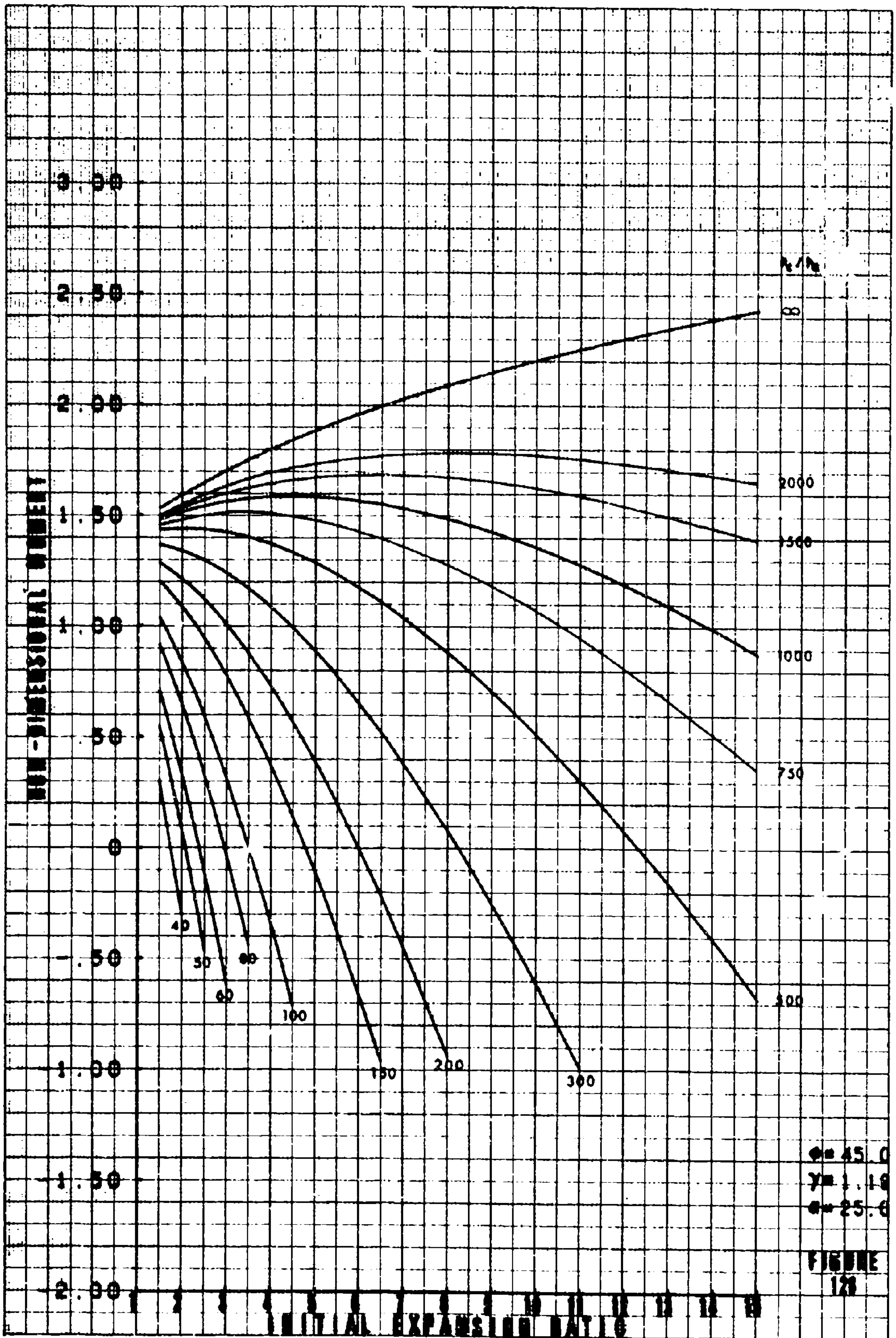
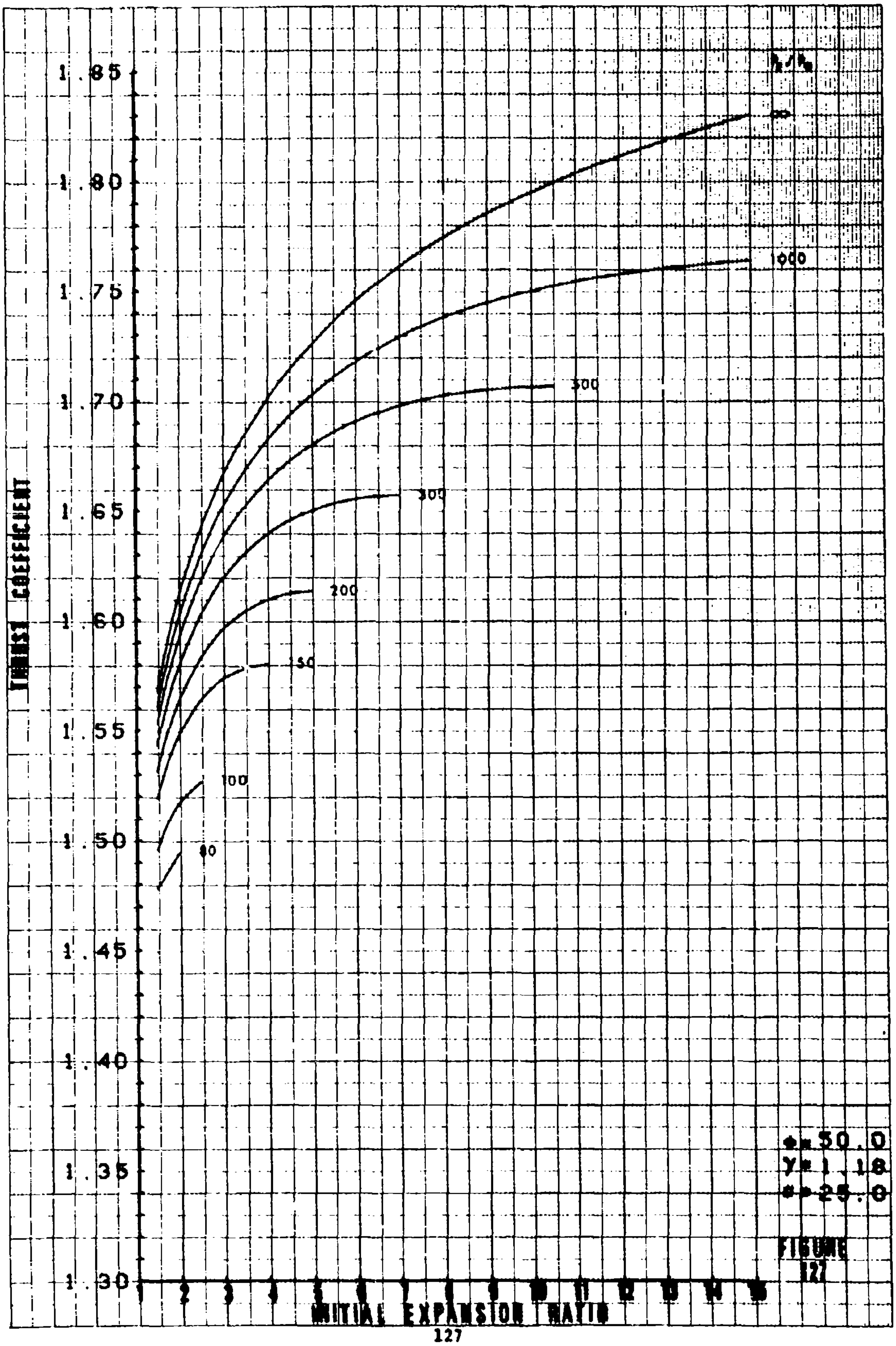
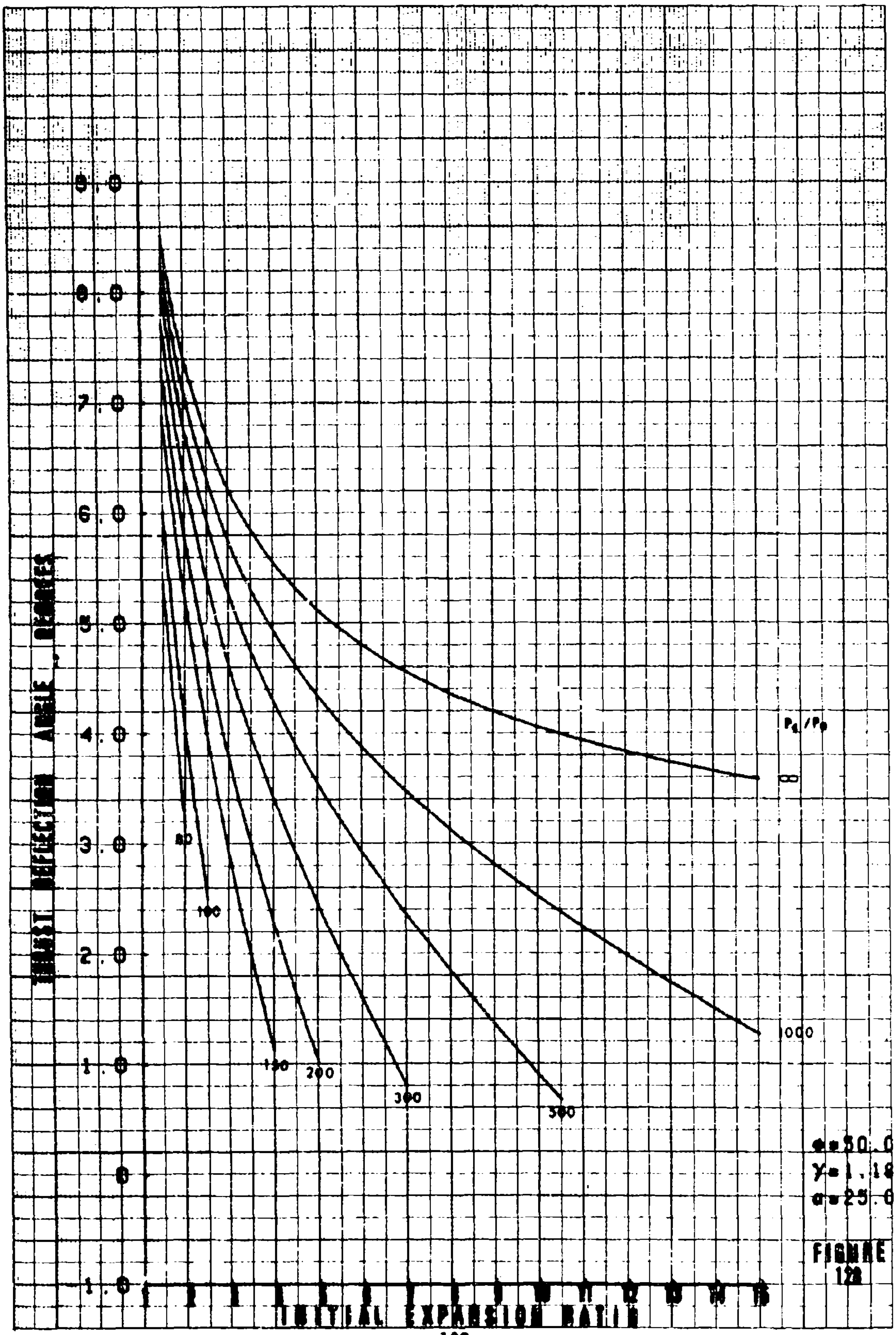

THRUST COEFFICIENT
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
INITIAL EXPANSION RATIO
P_c/P_a
∞
1000
500
300
200
150
100
80
60
50
40
φ = 45.0
γ = 1.18
ε = 25.0

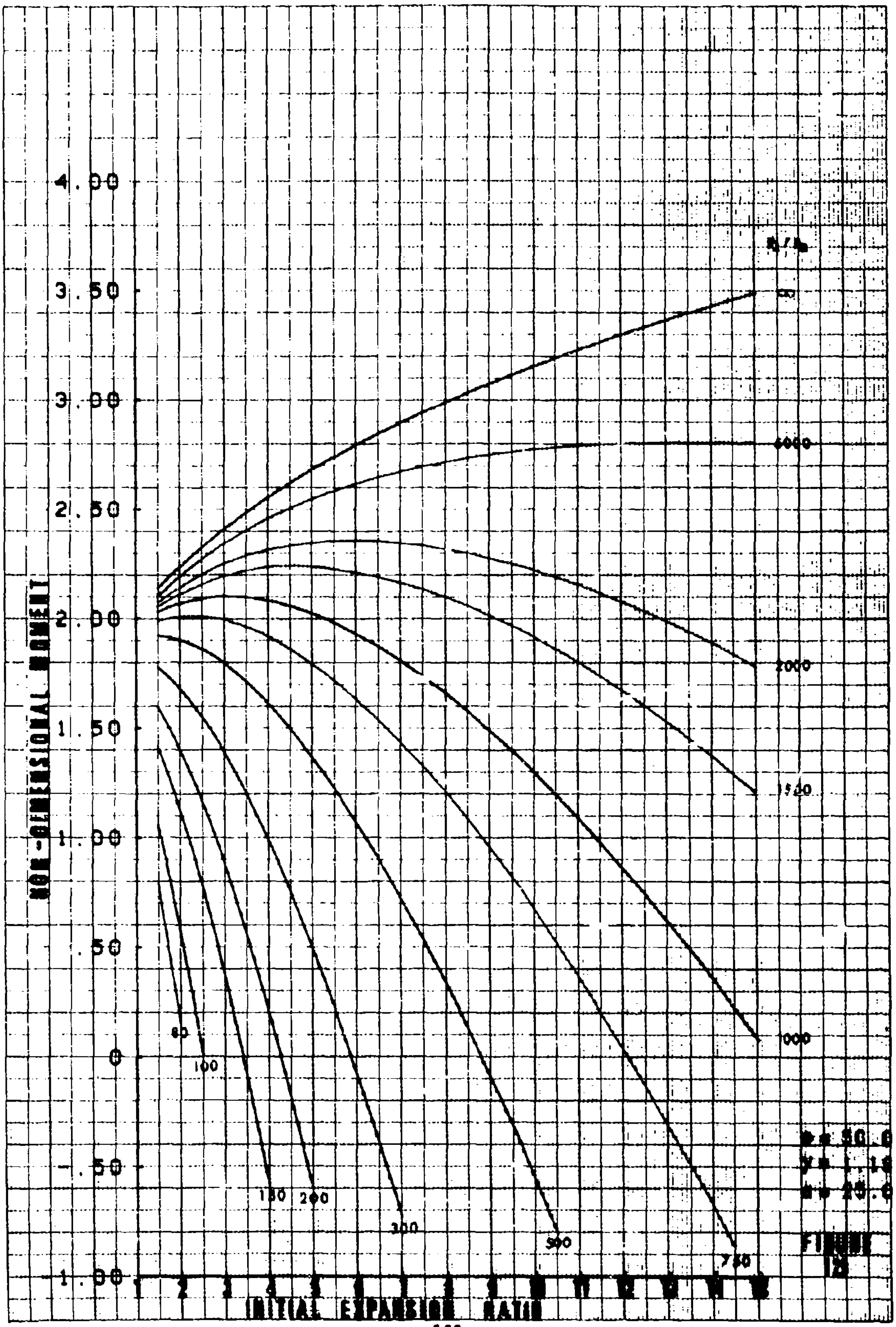
FIGURE 124


THRUST DEFLECTION ANGLE, DEGREES
INITIAL EXPANSION RATIO
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
-1.0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
∞
1000
300
40
50
60
80
100
150
200
250
FIGURE

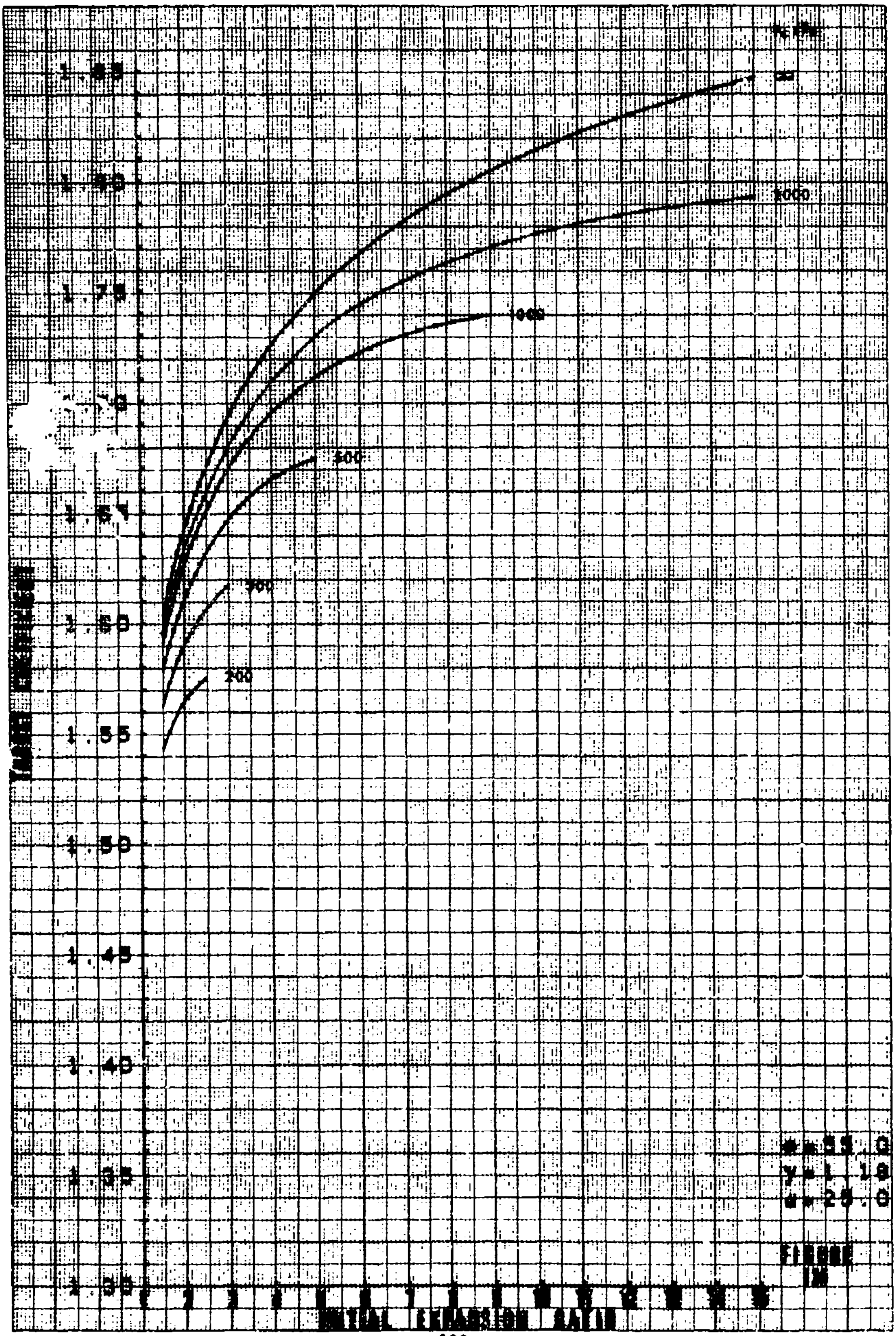

NON-DIMENSIONAL MOMENT
INITIAL EXPANSION RATIO
3.00
2.50
2.00
1.50
1.00
.50
0
-.50
-1.00
-1.50
-2.00
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
∞
2000
1500
1000
750
500
40
50
60
80
100
150
200
300
Φ=45.0
γ=1.10
α=25.0
FIGURE
123

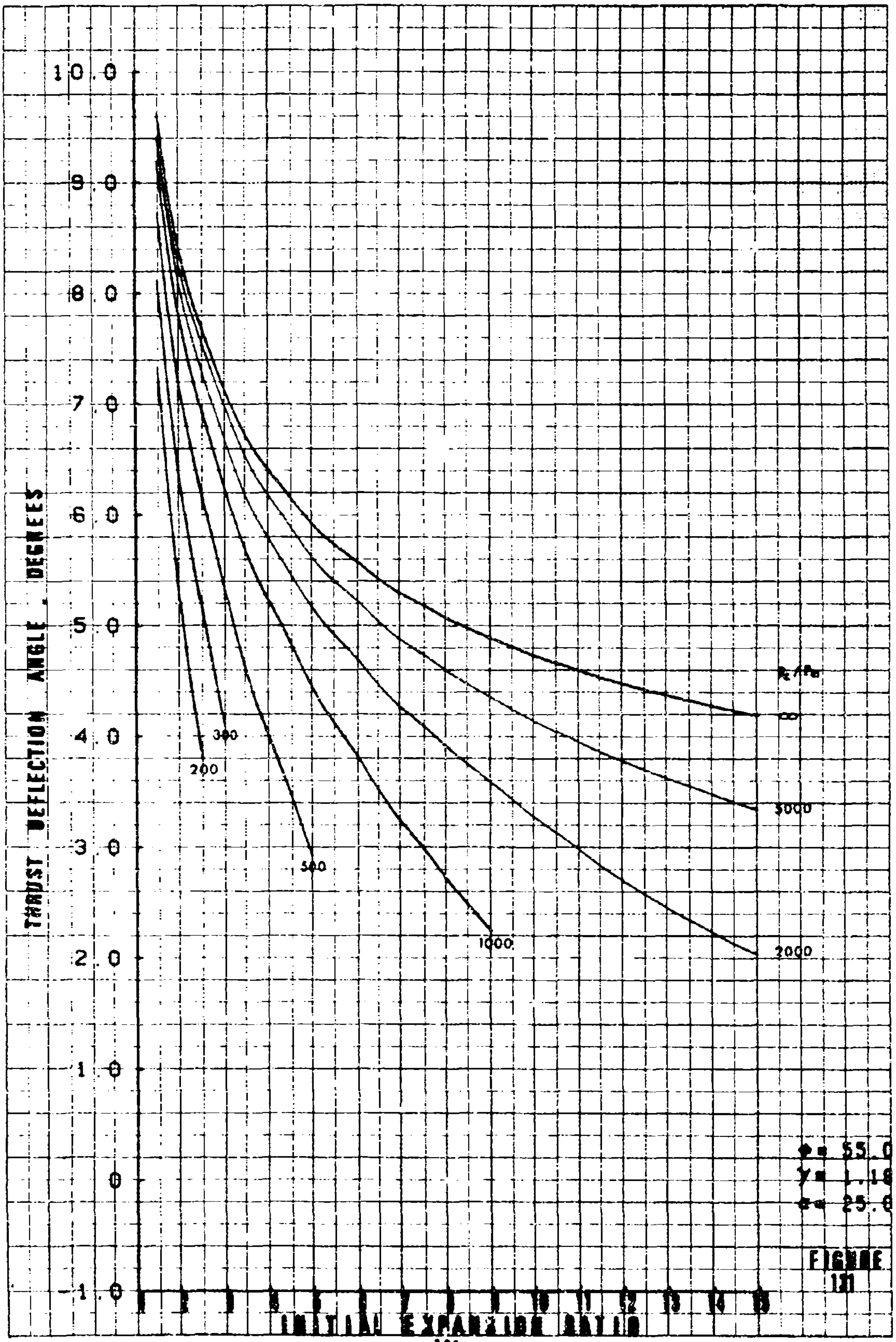

THRUST COEFFICIENT
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
INITIAL EXPANSION RATIO
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
∞
1000
500
300
200
150
100
80
φ=50.0
γ=1.18
θ=25.0
FIGURE 127

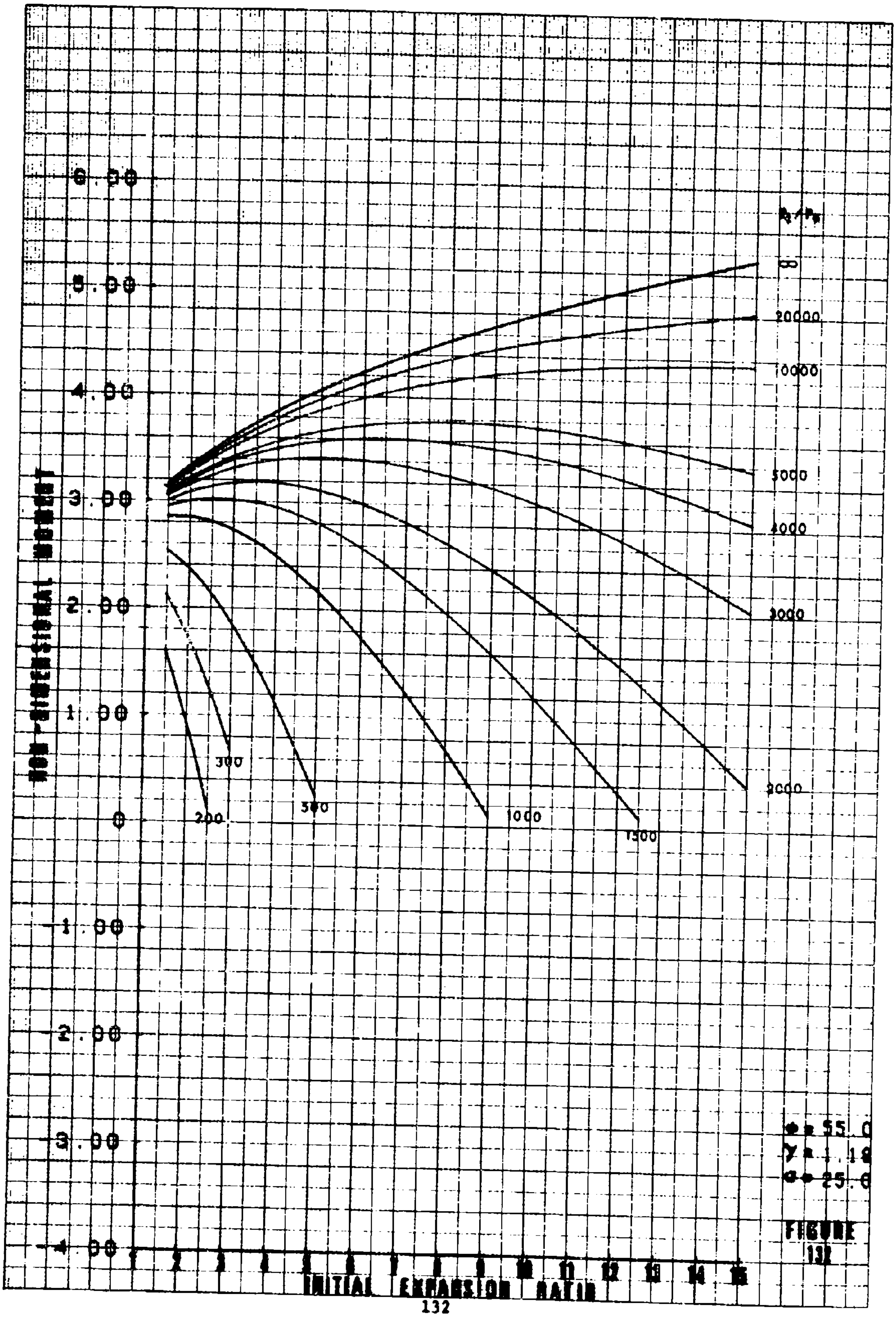

7.0
6.0
5.0
4.0
3.0
2.0
1.0
80
100
150
200
300
500
1000
∞
INITIAL EXPANSION RATIO



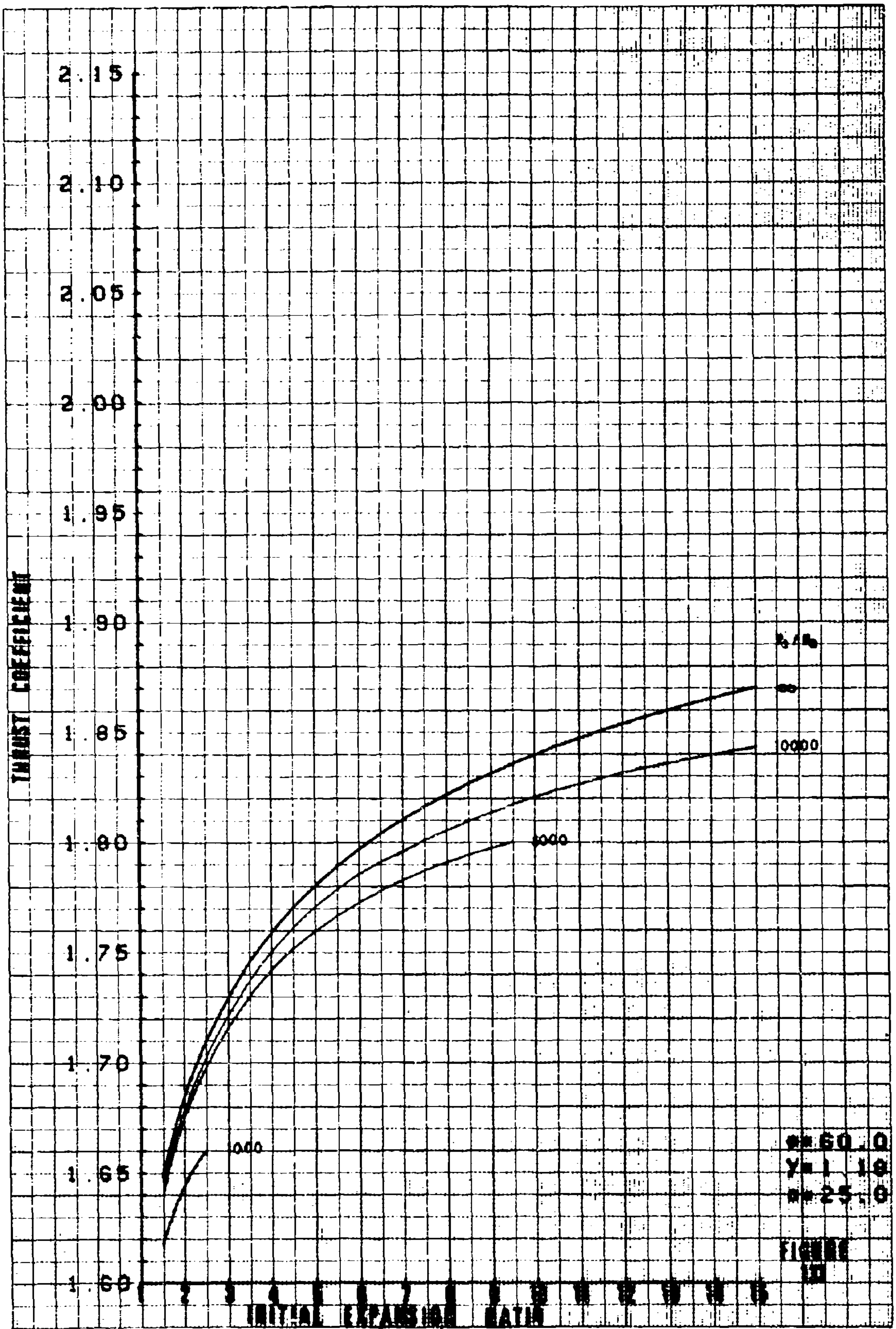
NON-DIMENSIONAL MOMENT
4.00
3.50
3.00
2.50
2.00
1.50
1.00
.50
0
-.50
-1.00
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
INITIAL EXPANSION RATIO
∞
6000
2000
1500
1000
750
500
300
200
150
100
80
FIGURE


1000
500
300
200
1.55
1.50
1.45
1.40


THRUST DEFLECTION ANGLE, DEGREES
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
-1.0
INITIAL EXPANSION RATIO
P_c/P_a
∞
5000
2000
1000
500
300
200
ϕ = 55.0
γ = 1.18
α = 25.0
FIGURE



6.00
5.00
4.00
3.00
2.00
1.00
0
-1.00
-2.00
-3.00
-4.00
NON-DIMENSIONAL MOMENT
INITIAL EXPANSION RATIO
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
P_c/P_a
∞
20000
10000
5000
4000
3000
2000
1500
1000
500
300
200
FIGURE 132


THRUST COEFFICIENT
INITIAL EXPANSION RATIO
2.15
2.10
2.05
2.00
1.95
1.90
1.85
1.80
1.75
1.70
1.65
1.60
10000
60.0
25.0
FIGURE

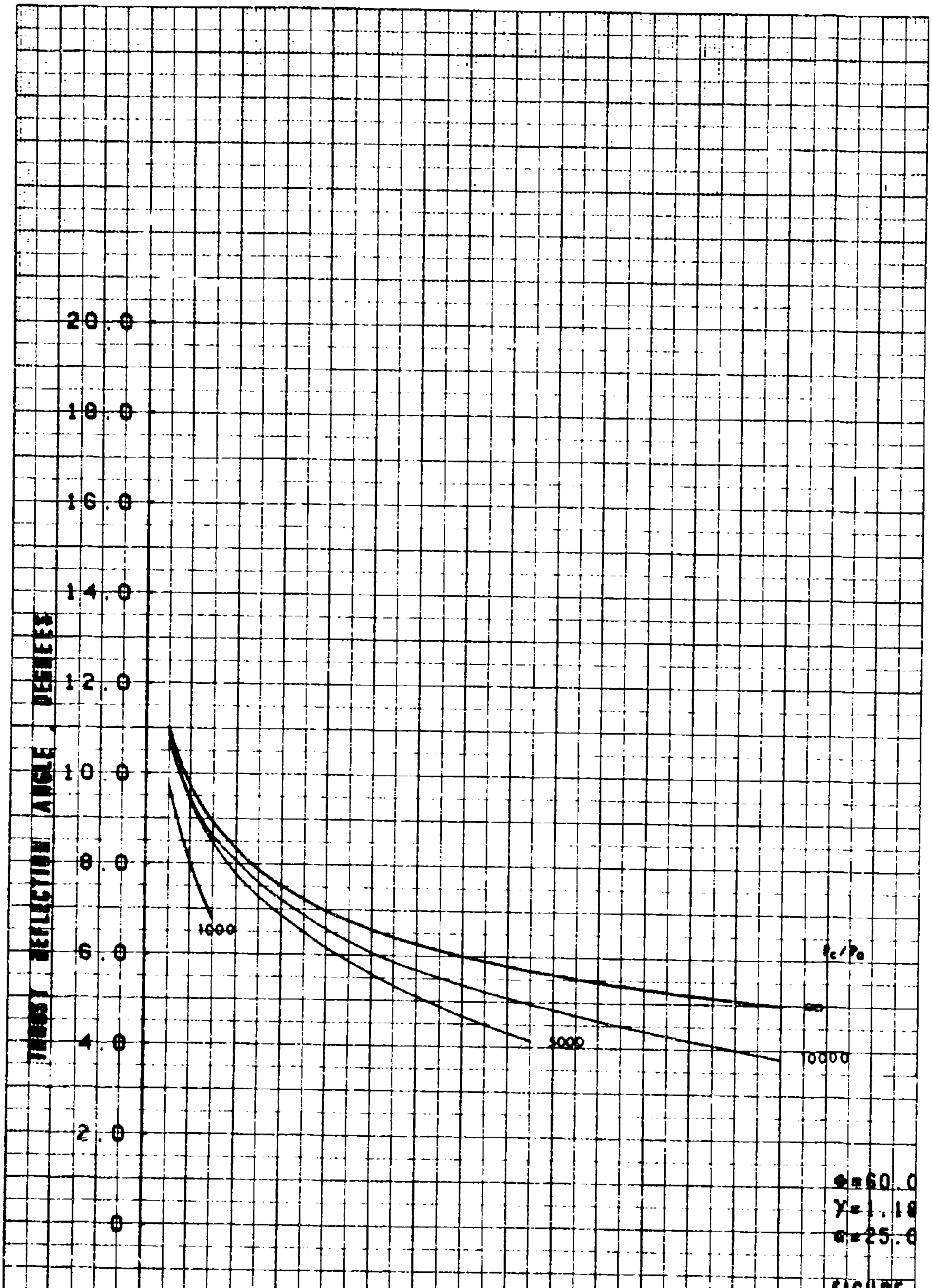
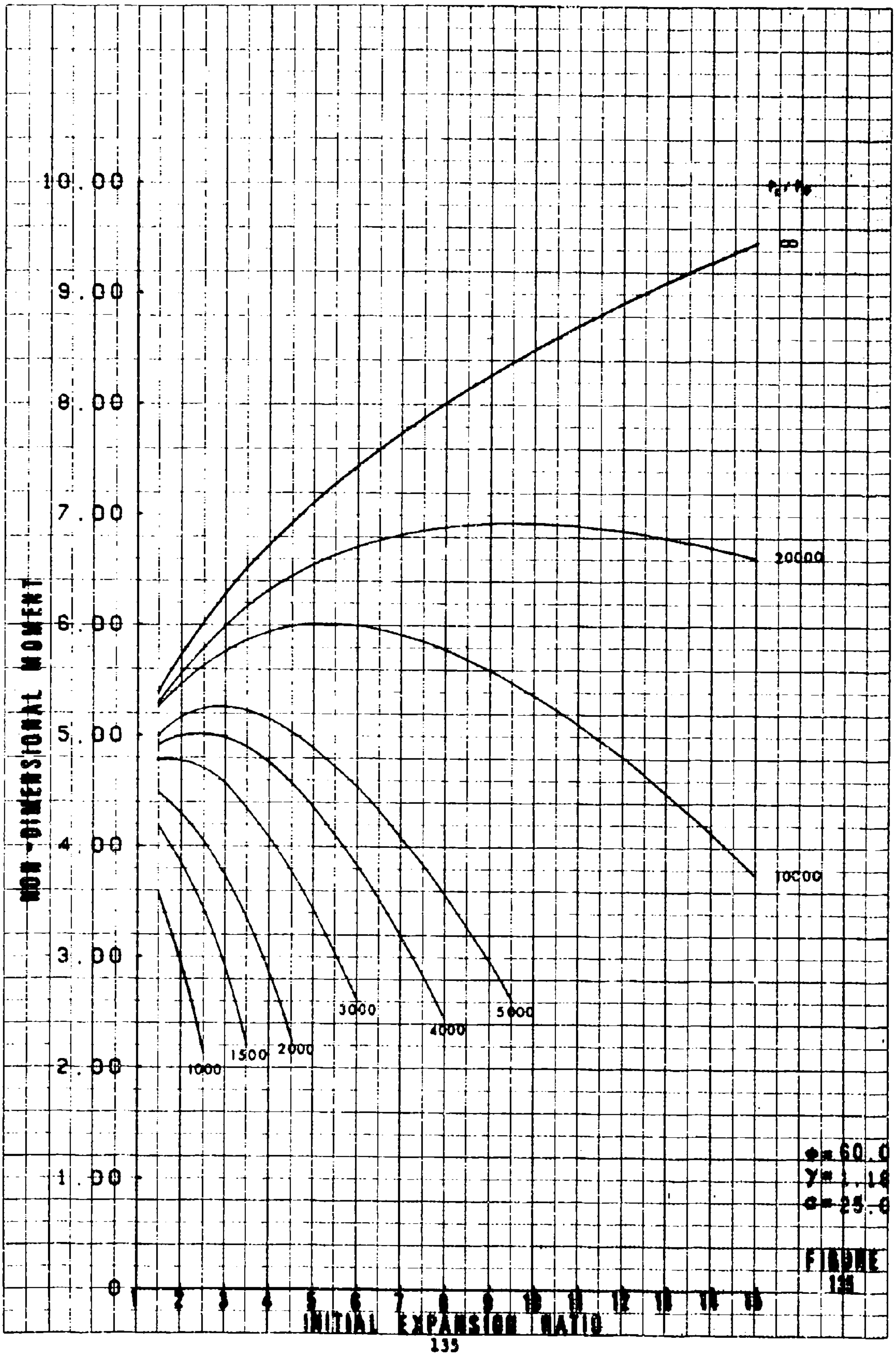
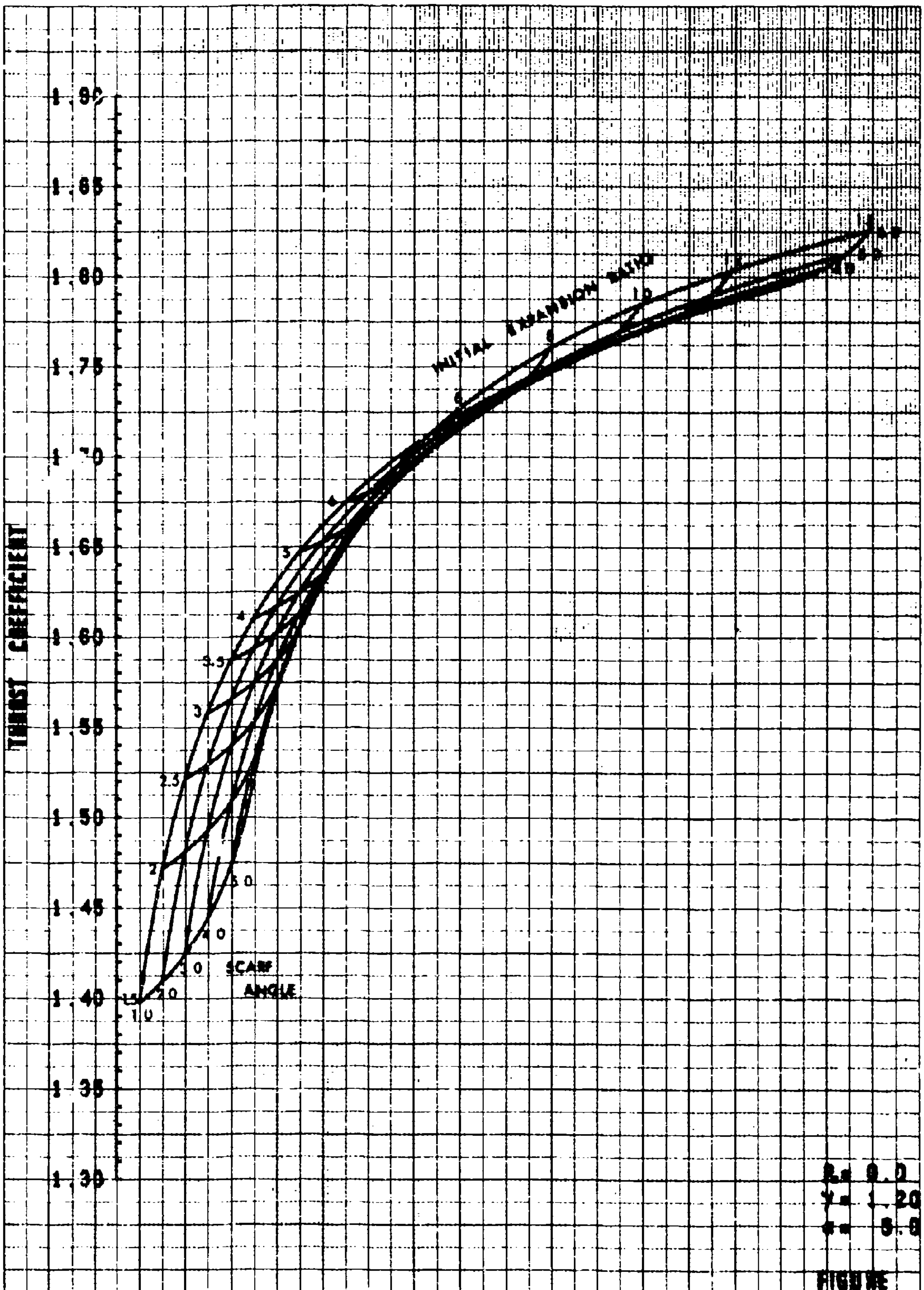
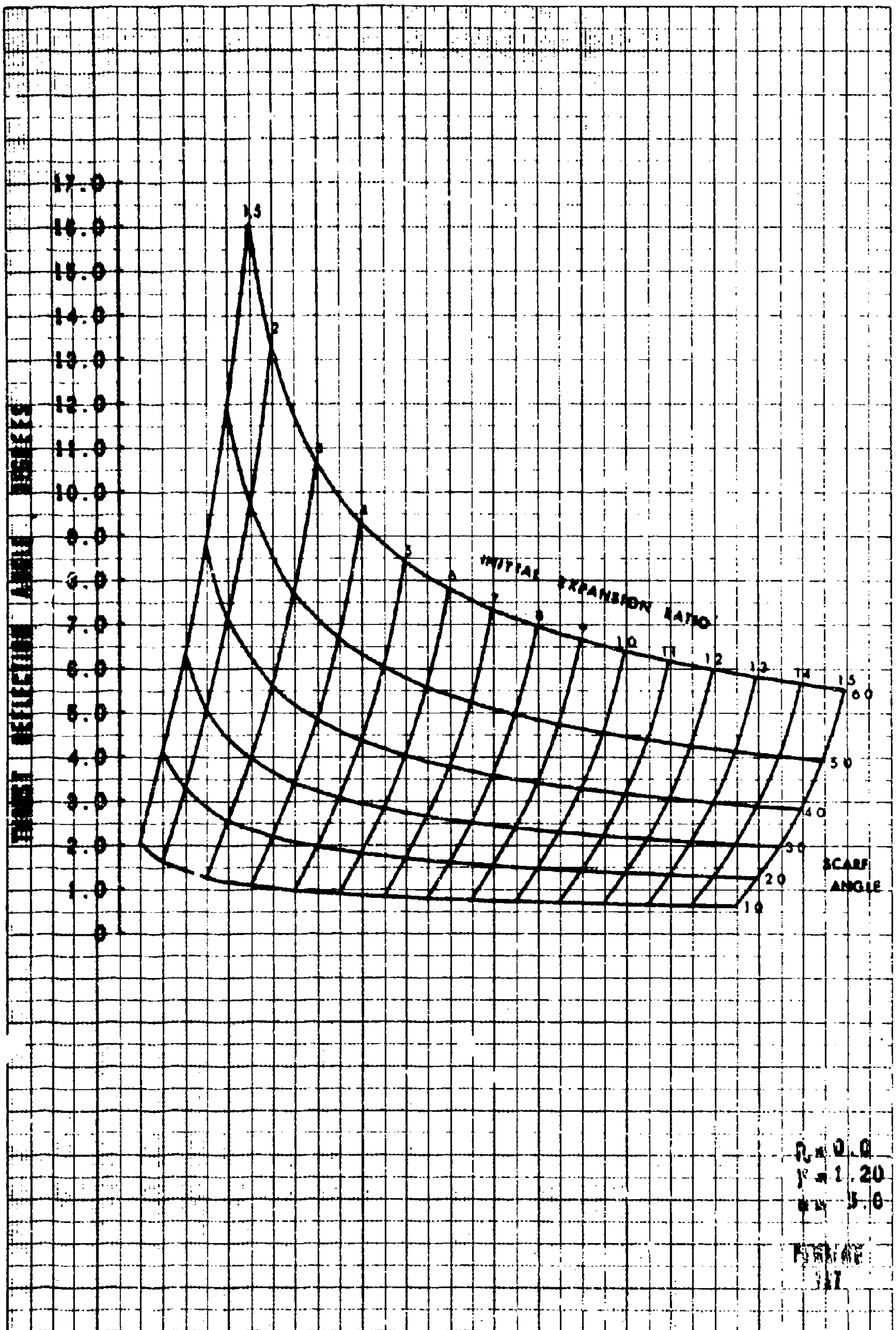
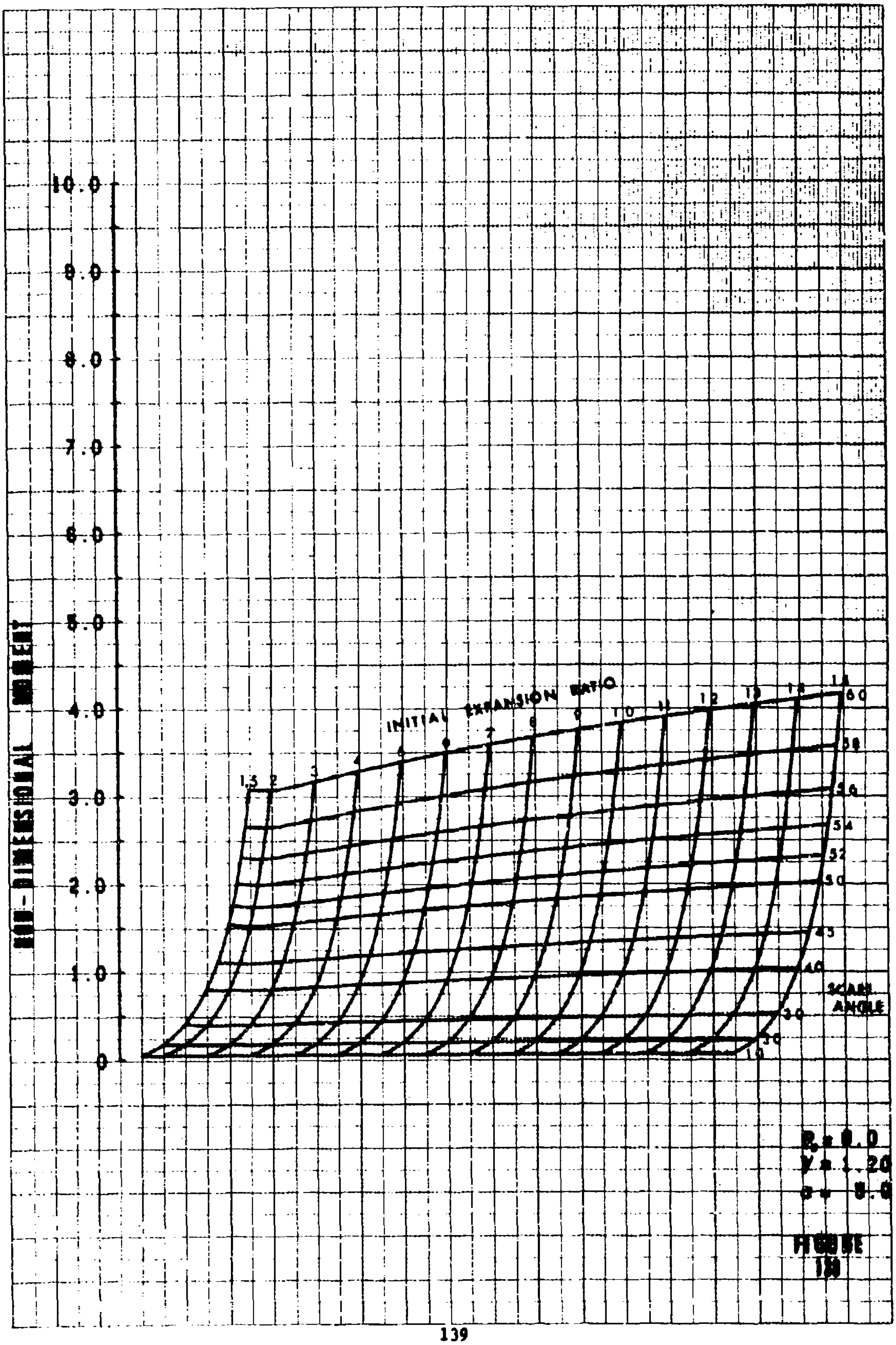

20.0
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0
-2.0
THRUST DEFLECTION ANGLE, DEGREES
1000
5000
10000
P_c/P_a
INITIAL EXPANSION RATIO
ϕ=60.0
γ=1.19
α=25.0

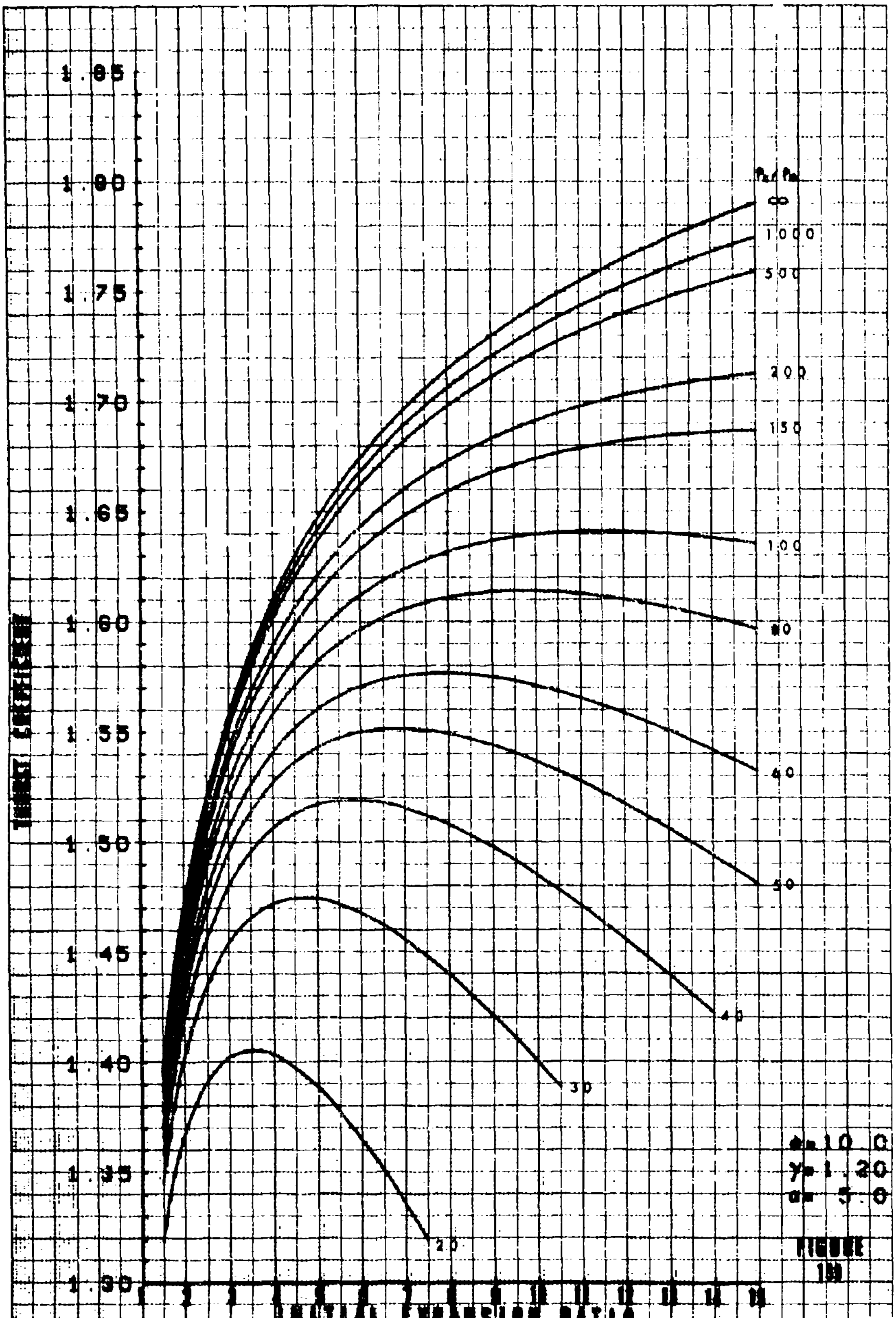
FIGURE 134

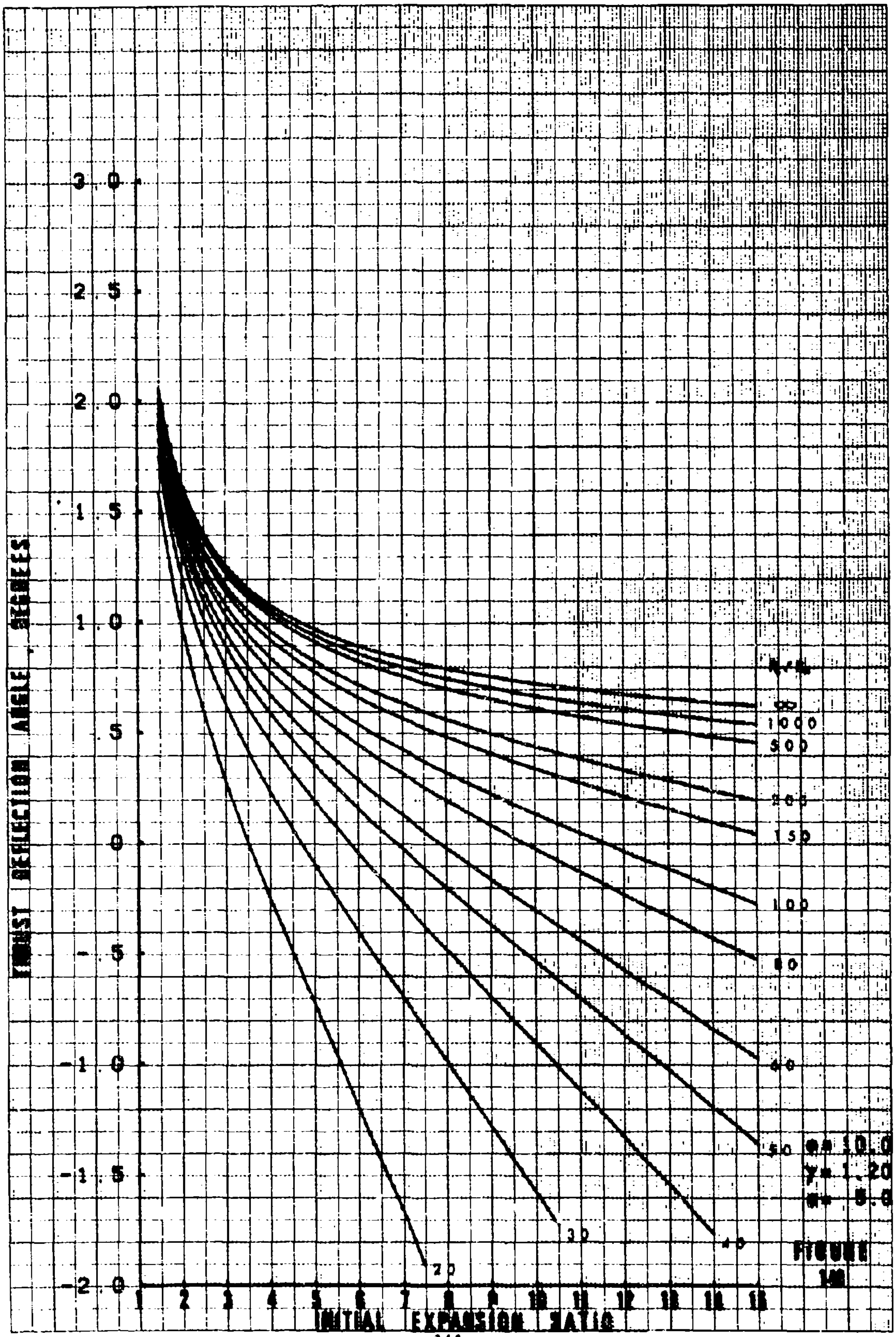

NON-DIMENSIONAL MOMENT
INITIAL EXPANSION RATIO
10.00
9.00
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
∞
20000
10000
5000
4000
3000
2000
1500
1000


THRUST COEFFICIENT
1.90
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
INITIAL EXPANSION RATIO
SCARF
ANGLE
FIGURE
1M


17.0
16.0
15.0
14.0
13.0
12.0
11.0
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
INITIAL EXPANSION RATIO
1.5
2
3
4
5
6
7
8
9
10
11
12
13
14
15
60
50
40
30
20
10
SCARF ANGLE
1.20
FIGURE


NON-DIMENSIONAL MOMENT
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
INITIAL EXPANSION RATIO
1.5
2
3
4
5
6
7
8
9
10
11
12
13
14
15
SCAN ANGLE
60
58
56
54
52
50
45
40
30
20
10
FIGURE


1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
∞
1000
500
200
150
100
60
50
40
30
20
γ= 1.20
FIGURE


THRUST DEFLECTION ANGLE, DEGREES
INITIAL EXPANSION RATIO
3.0
2.5
2.0
1.5
1.0
.5
0
-.5
-1.0
-1.5
-2.0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
∞
1000
500
200
150
100
80
60
50
40
30
20
10.0
γ = 1.20
5.0
FIGURE

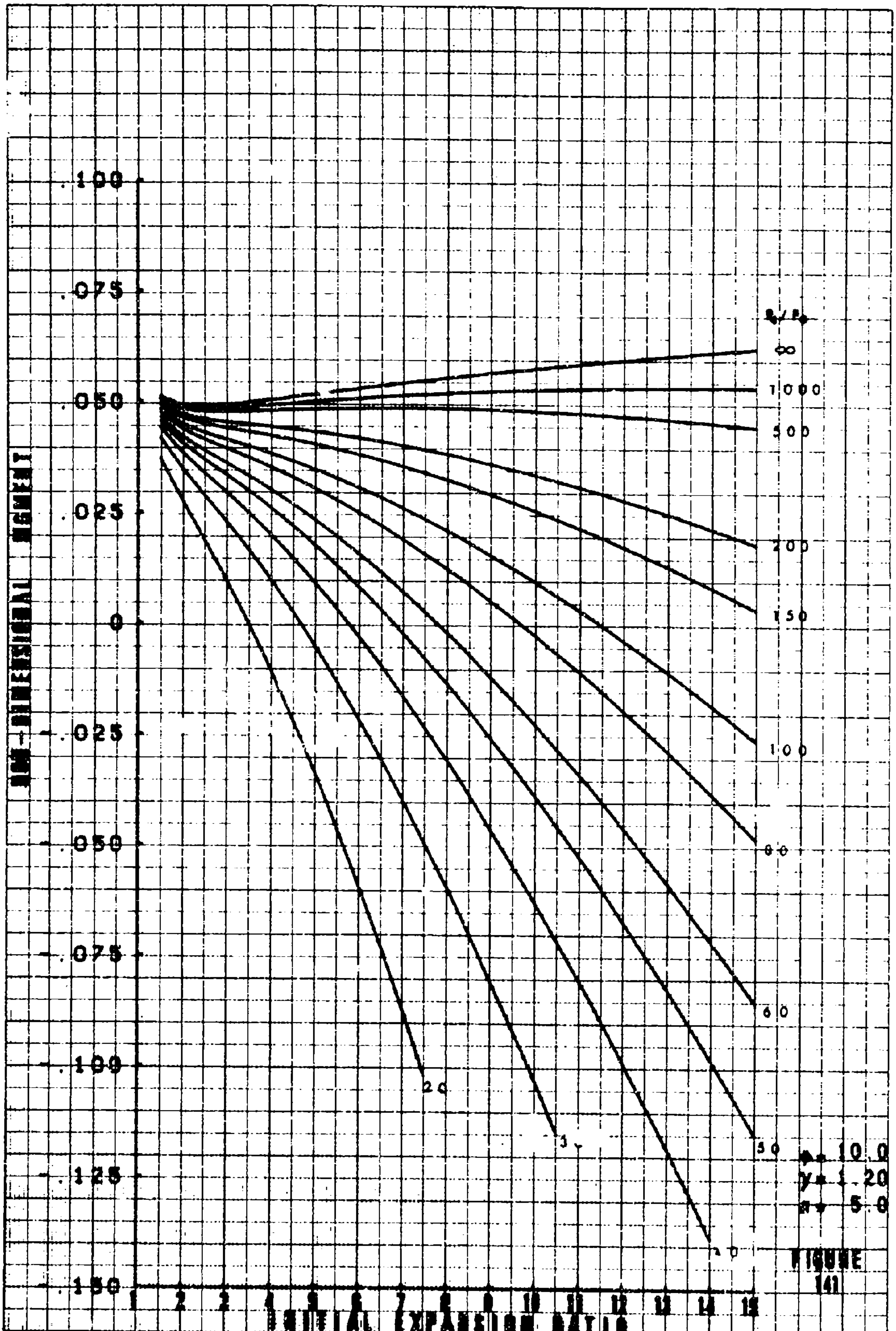
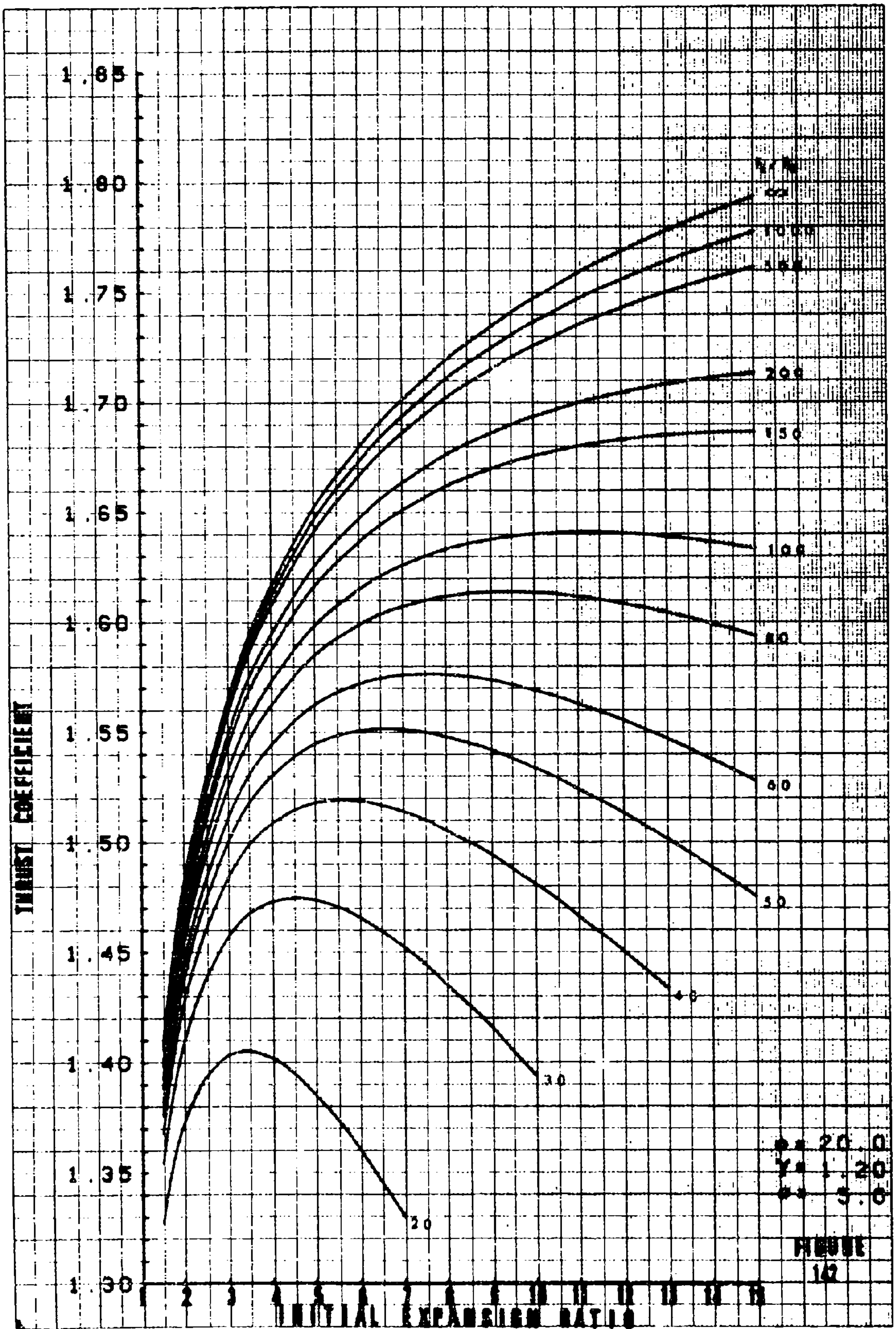
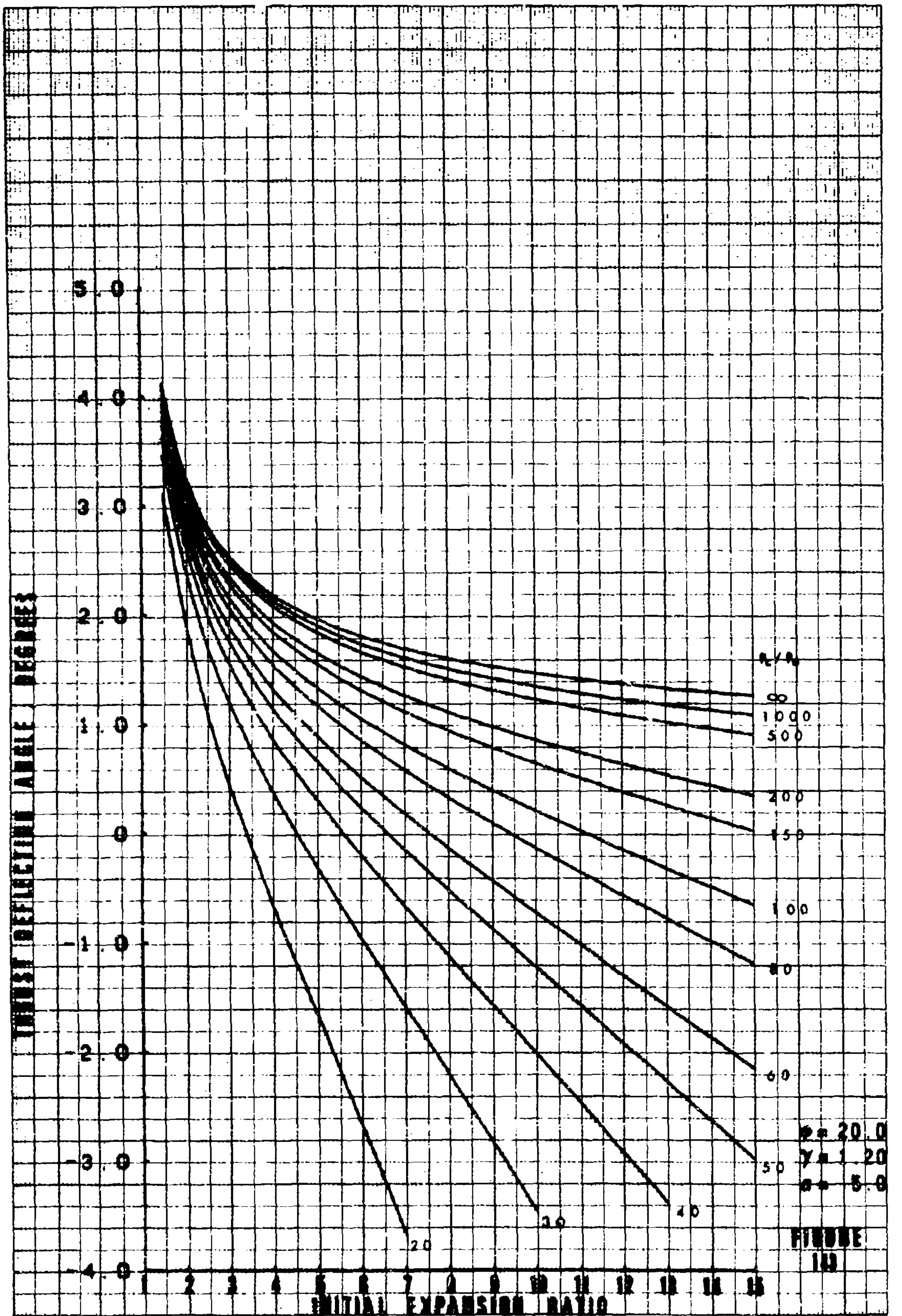

NON-DIMENSIONAL MOMENT
.100
.075
.050
.025
0
-.025
-.050
-.075
-.100
-.125
-.150
INITIAL EXPANSION RATIO
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
∞
1000
500
200
150
100
80
60
50
20
ϕ = 10.0
γ = 1.20
5.0

FIGURE 141


THRUST COEFFICIENT
INITIAL EXPANSION RATIO
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
∞
1000
500
200
150
100
80
60
50
40
30
20
Φ= 20.0
γ= 1.20
θ= 5.0
FIGURE
142


THRUST DEFLECTING ANGLE DEGREES
5.0
4.0
3.0
2.0
1.0
0
-1.0
-2.0
-3.0
-4.0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
INITIAL EXPANSION RATIO
∞
1000
500
200
150
100
80
60
50
40
30
20
= 20.0
γ = 1.20
5.0
FIGURE

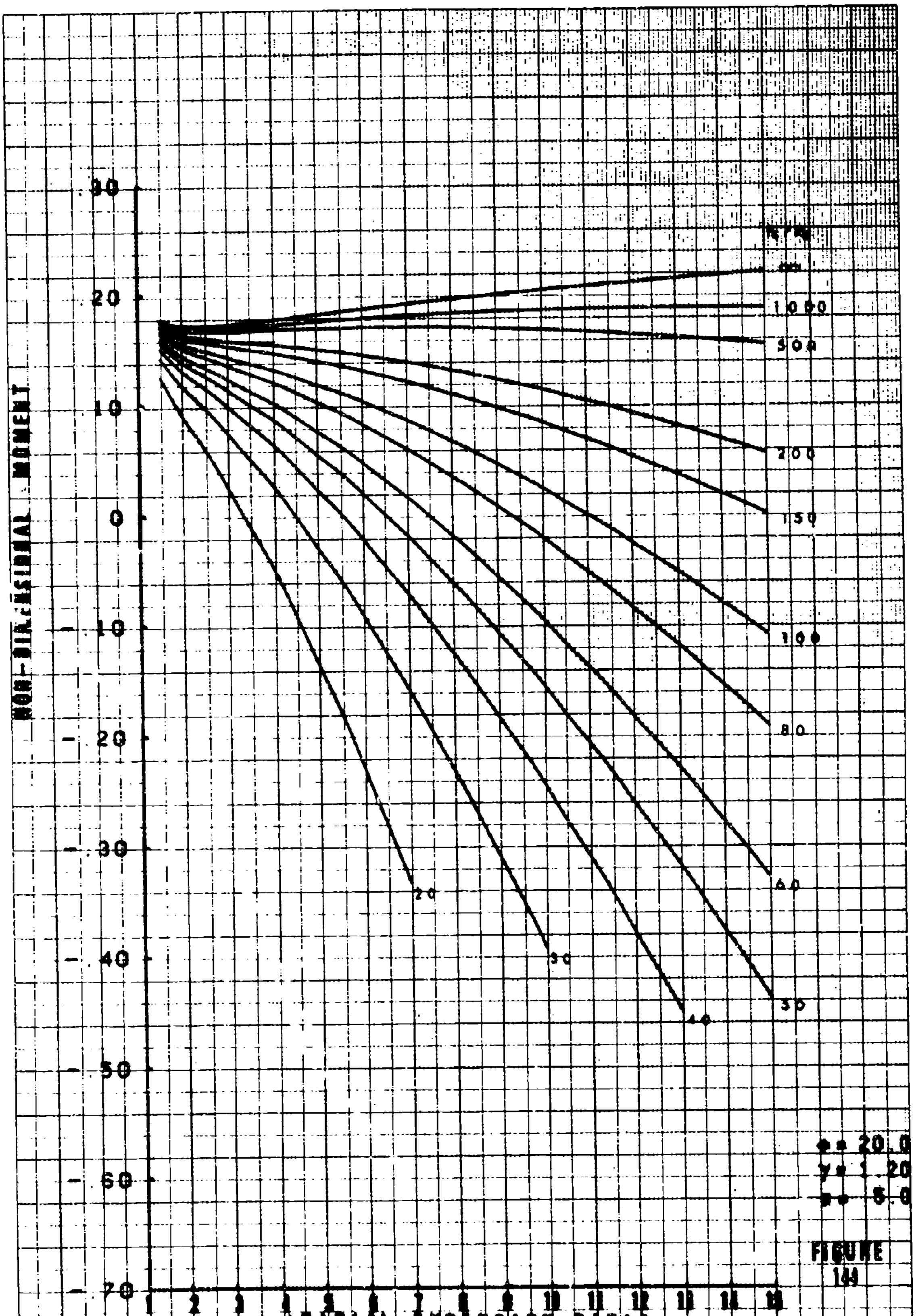
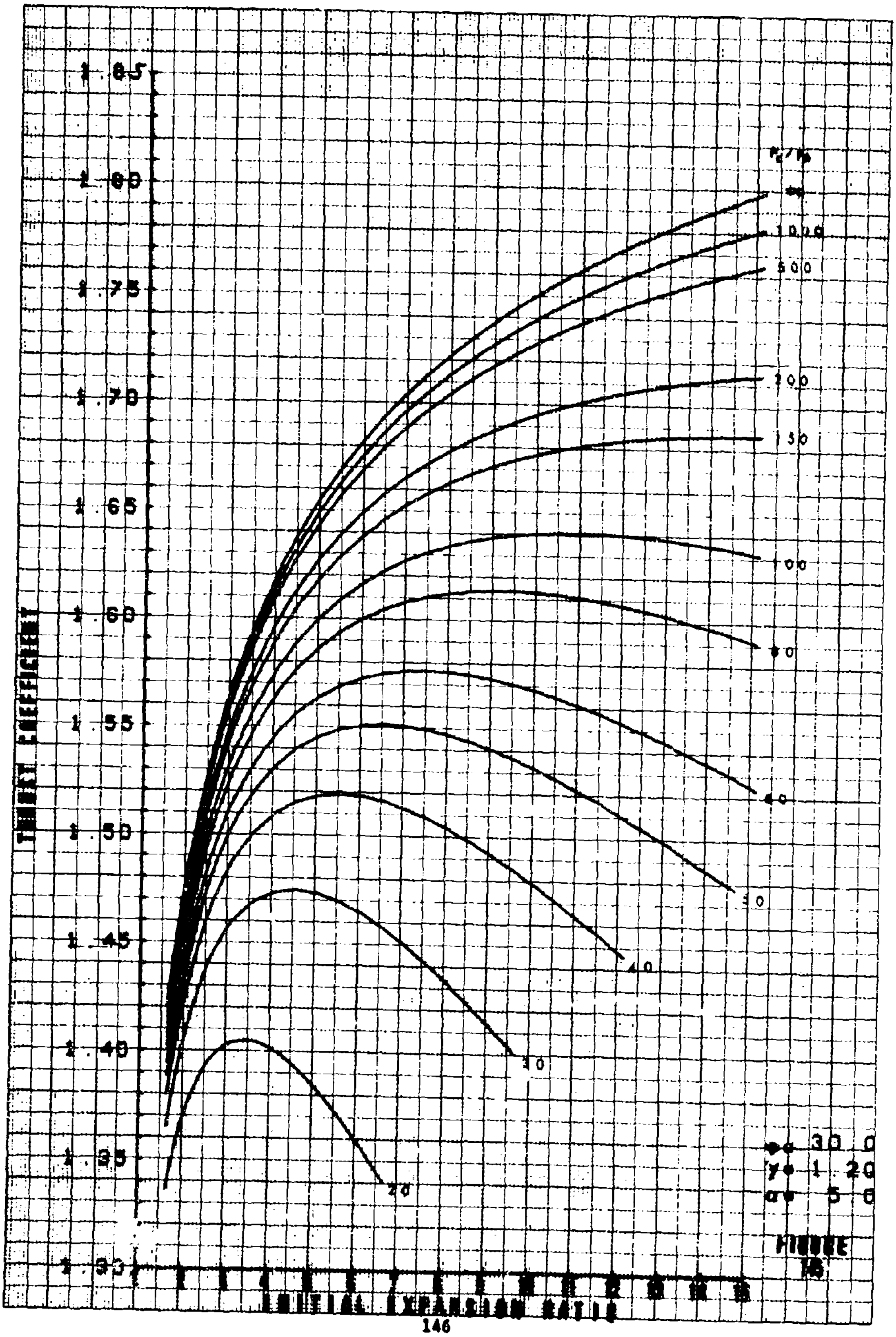
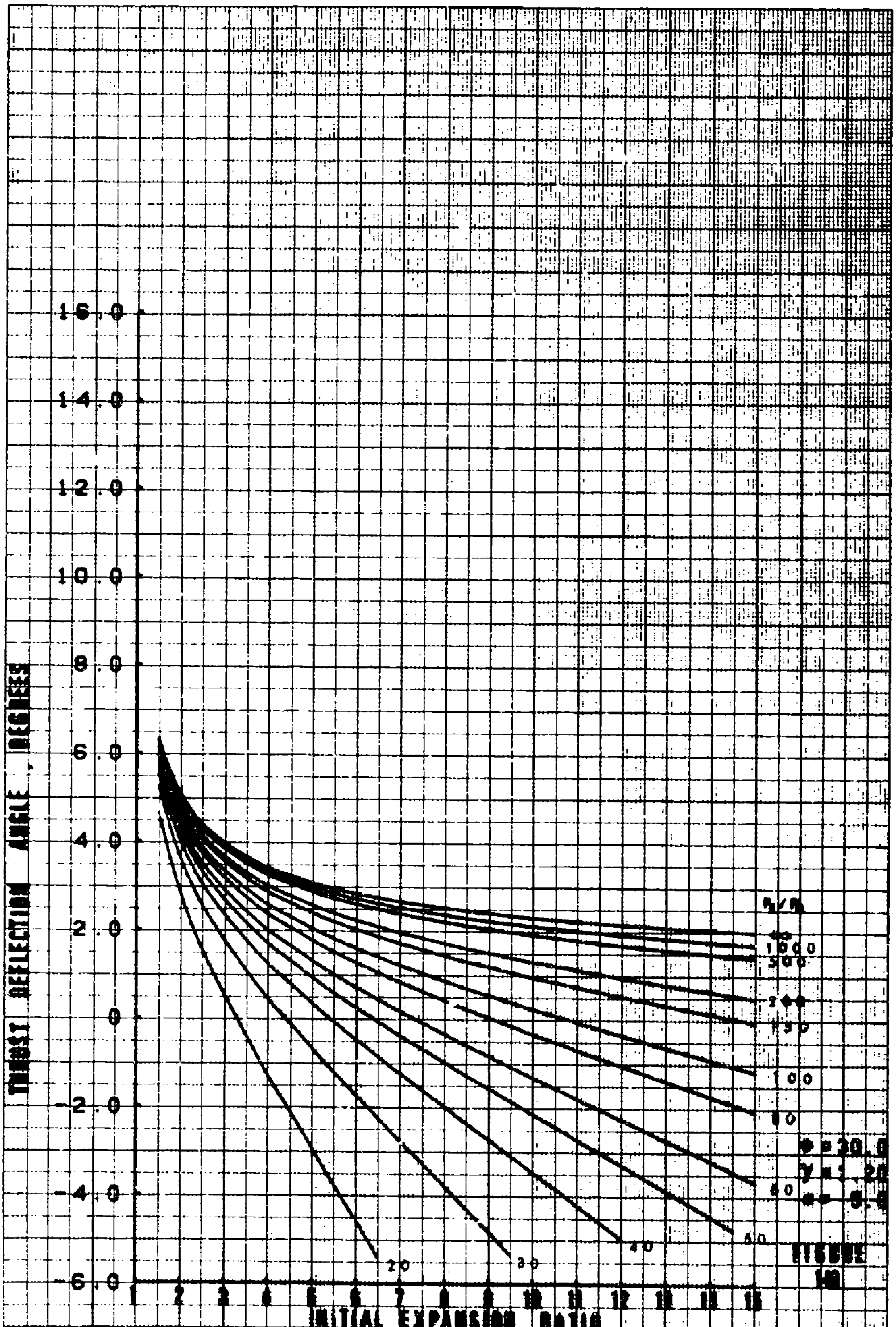

NON-DIMENSIONAL MOMENT
INITIAL EXPANSION RATIO
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
1000
500
200
150
100
80
60
50
40
30
20
= 20.0
= 1.20
= 5.0

FIGURE 144

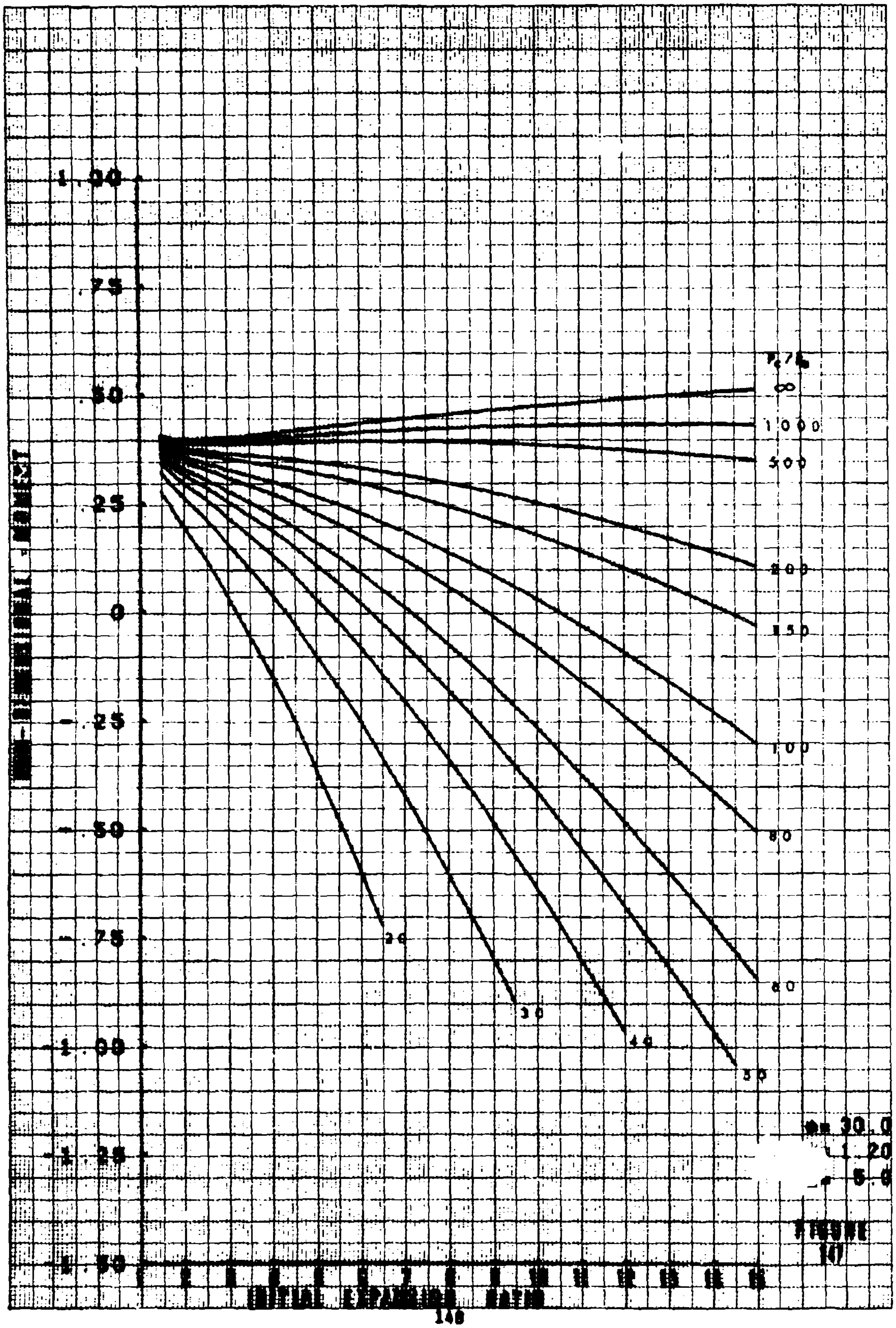


THRUST COEFFICIENT
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
INITIAL EXPANSION RATIO
P_c/P_a
∞
1000
500
200
150
100
80
60
50
40
30
20

FIGURE 16

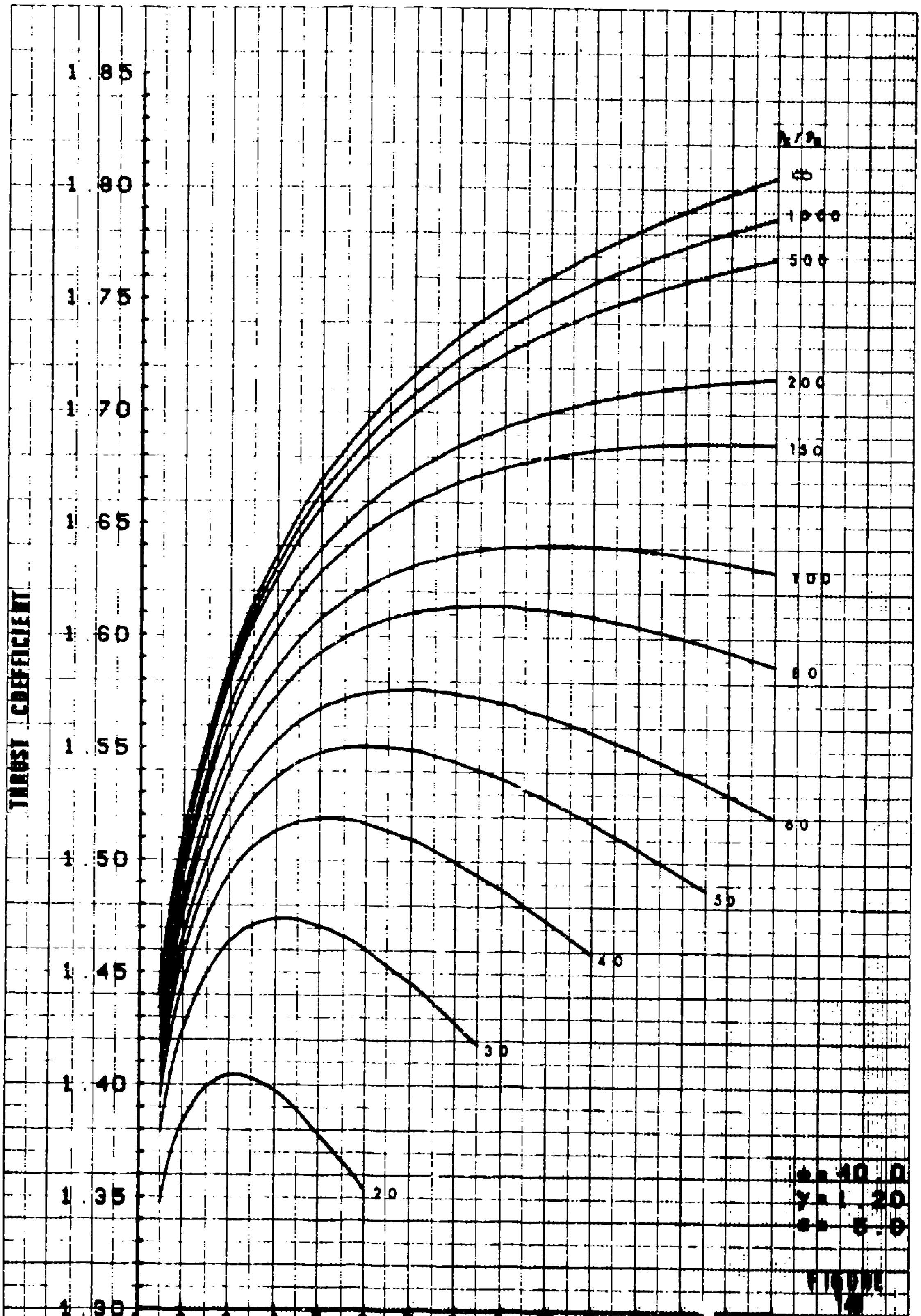


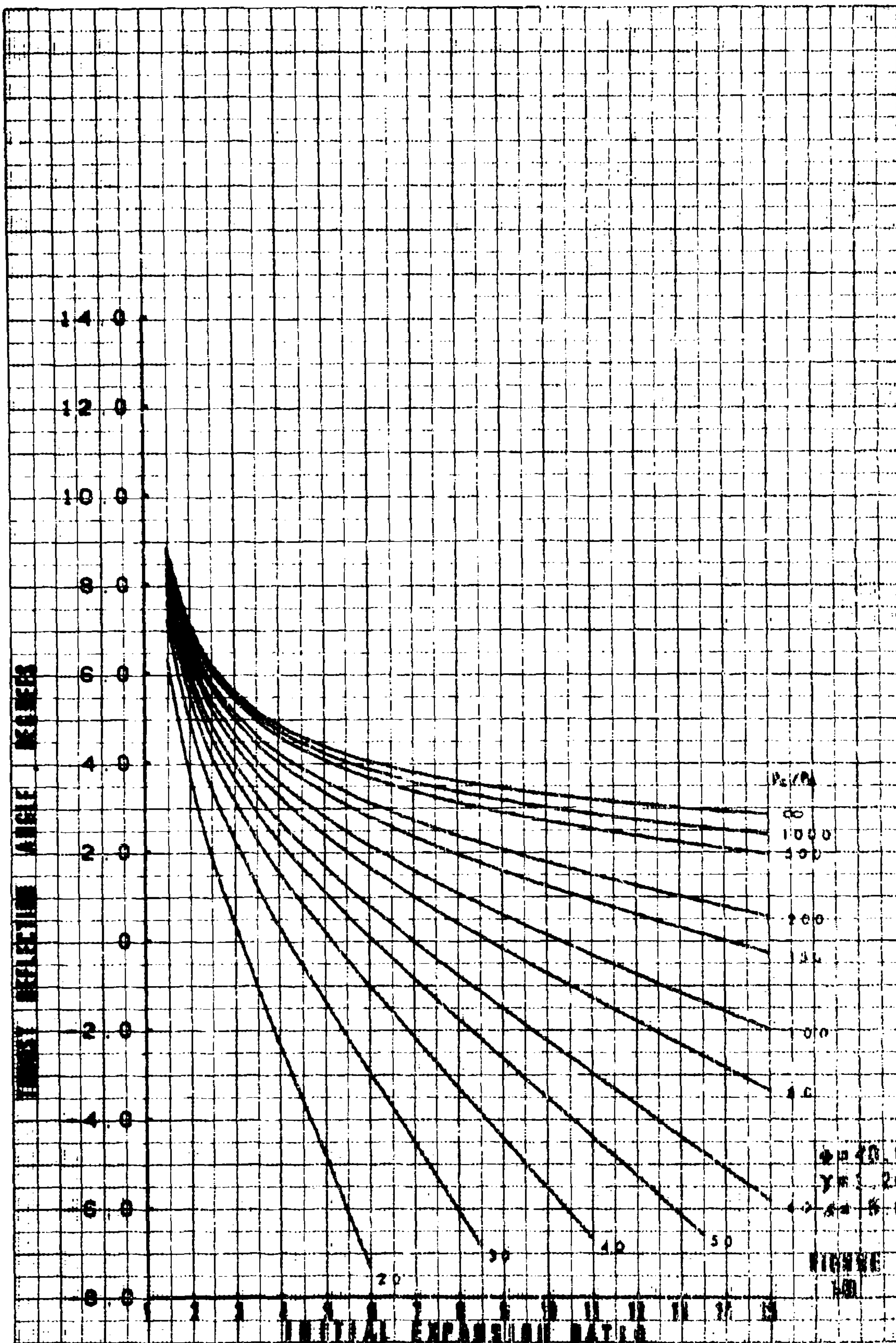
THRUST DEFLECTION ANGLE, DEGREES
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0
-2.0
-4.0
-6.0
1
2
INITIAL EXPANSION RATIO
1000
100
80
60
50
40
30
20
FIGURE

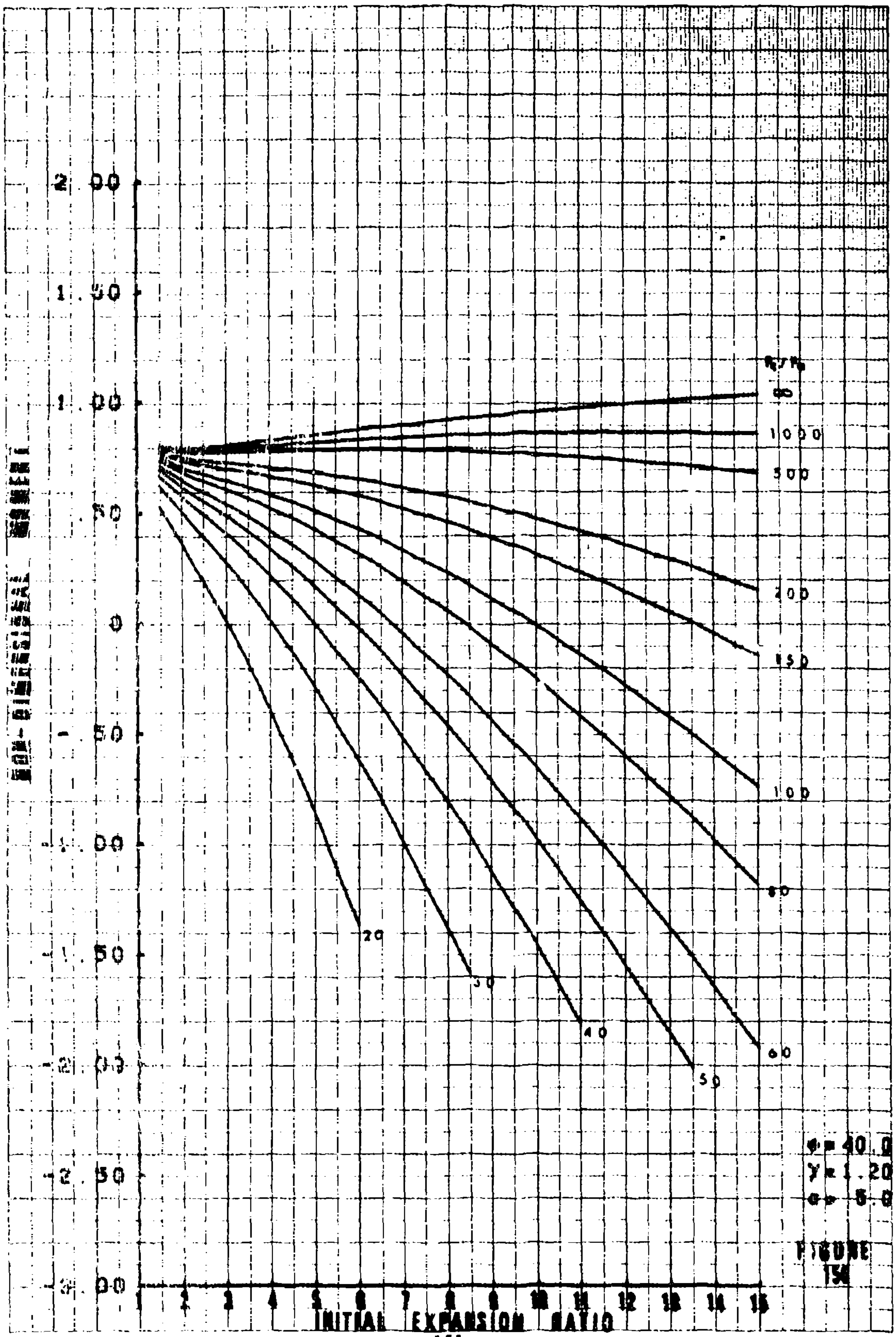


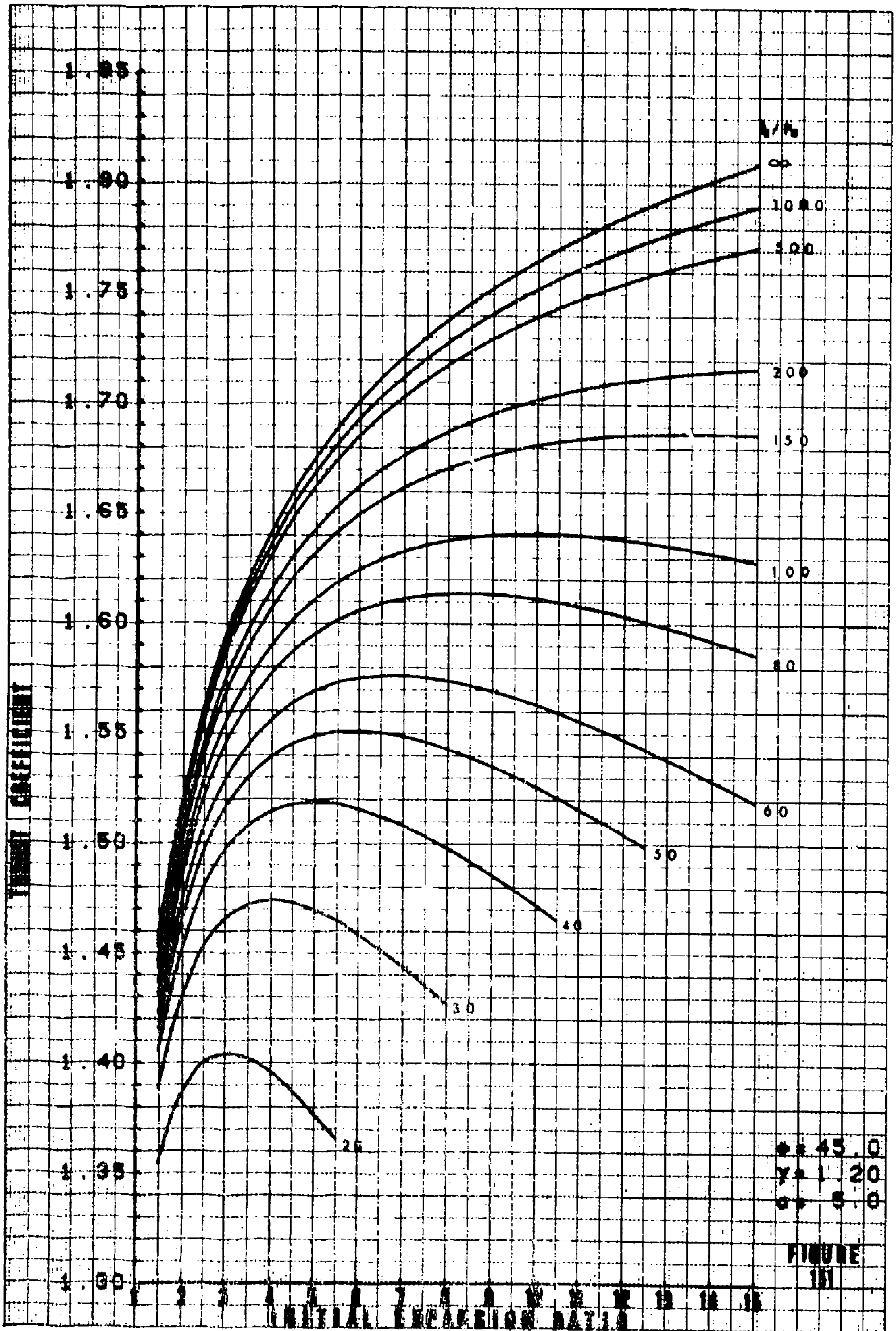
1.00
.75
.50
.25
0
-.25
-.50
-.75
-1.00
-1.25
-1.50
∞
1000
500
200
150
100
80
60
50
40
30
20
INITIAL EXPANSION RATIO
= 30.0
1.20
5.0

FIGURE


THRUST COEFFICIENT
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
INITIAL EXPANSION RATIO
∞
1000
500
200
150
100
80
60
50
40
30
20
40.0
1.20
5.0
FIGURE


14.0
12.0
10.0
8.0
6.0
4.0
2.0
0
-2.0
-4.0
-6.0
-8.0
∞
1000
200
20
30
40
50


2.00
1.50
1.00
.50
0
-.50
-1.00
-1.50
-2.00
-2.50
-3.00
∞
1000
500
200
150
100
80
60
50
40
30
20
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
40.0
1.20


THRUST COEFFICIENT
INITIAL EXPANSION RATIO
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
∞
1000
500
200
150
100
80
60
50
40
30
25
θ = 45.0
γ = 1.20
α = 5.0
FIGURE 151

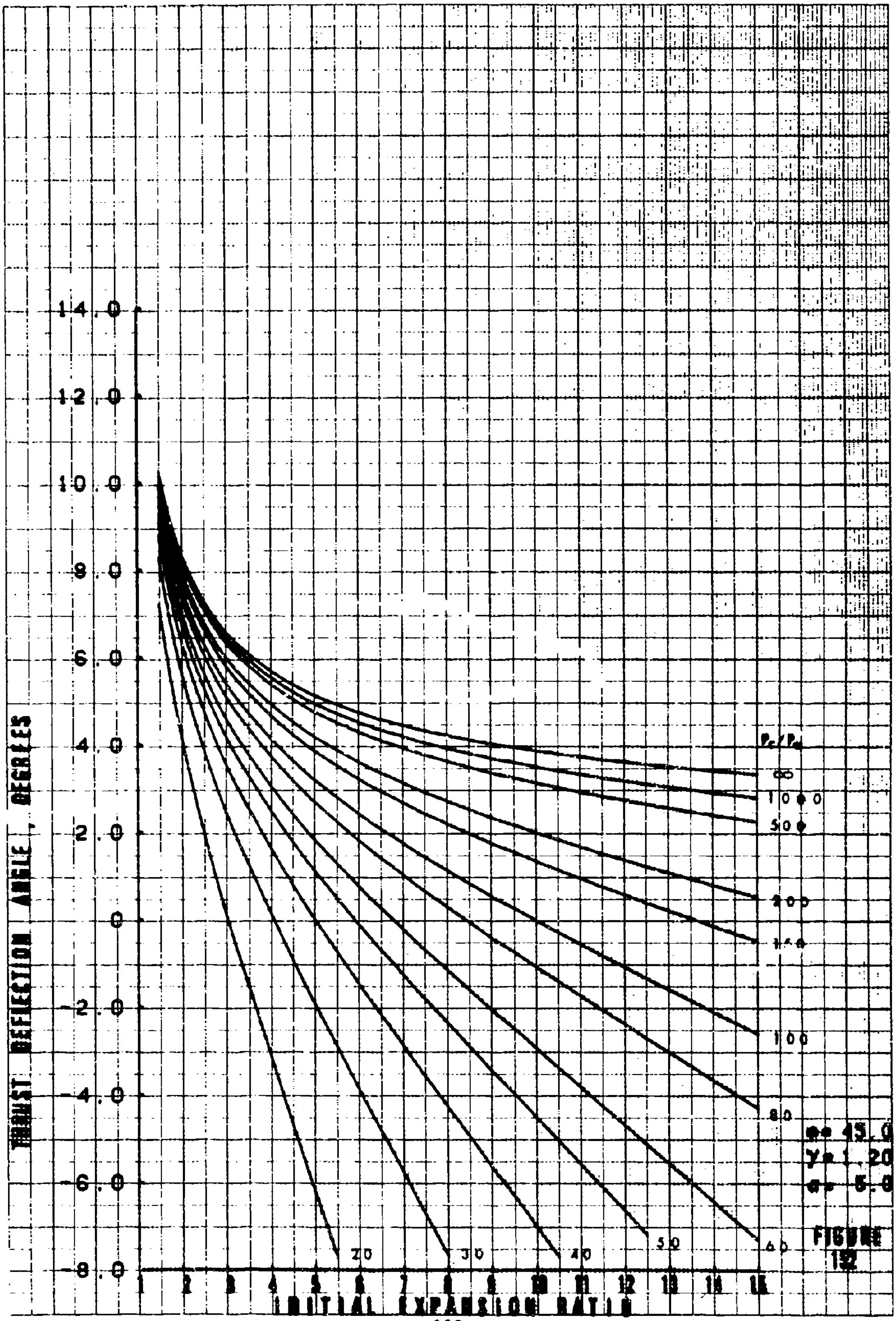
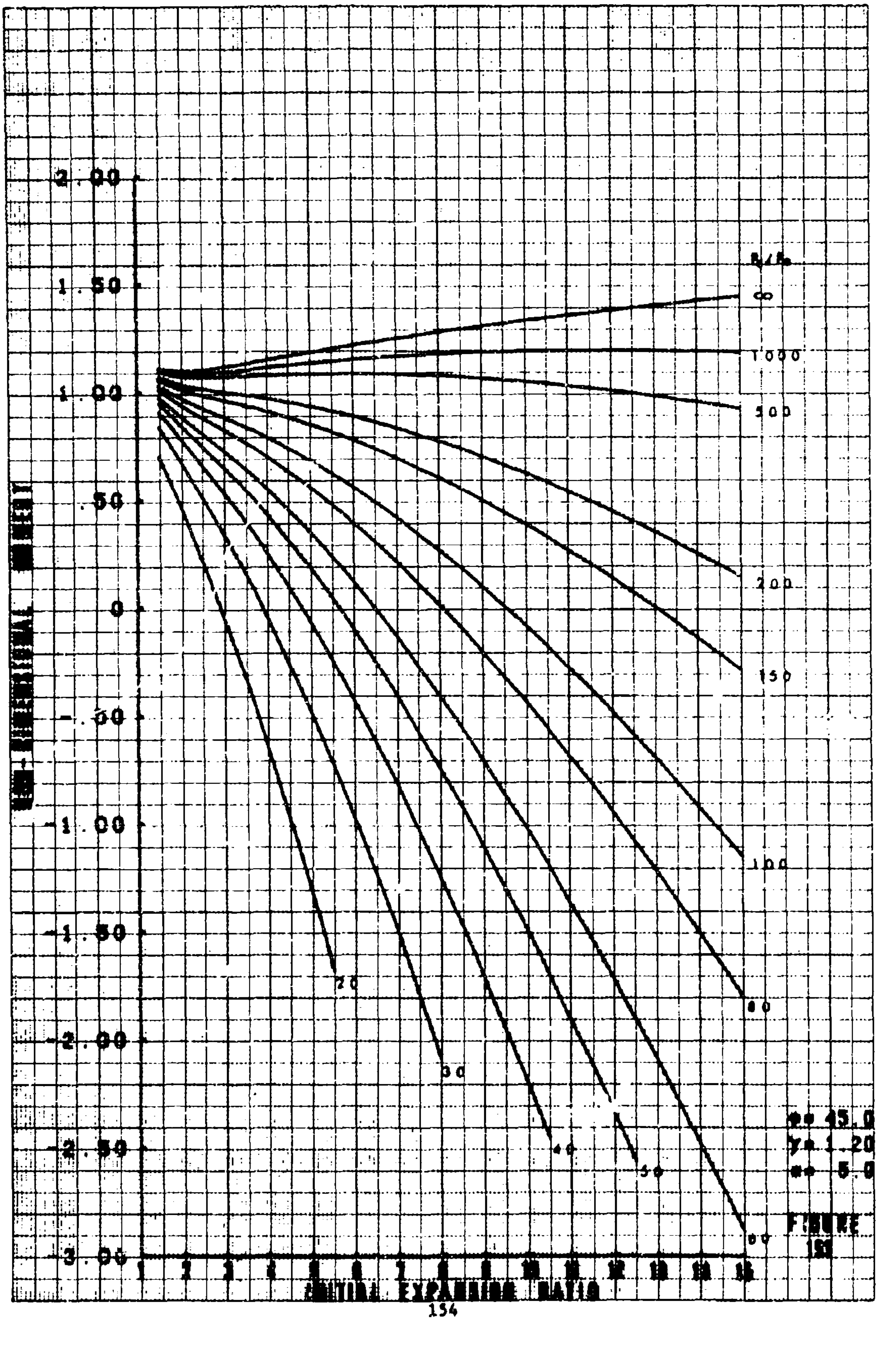
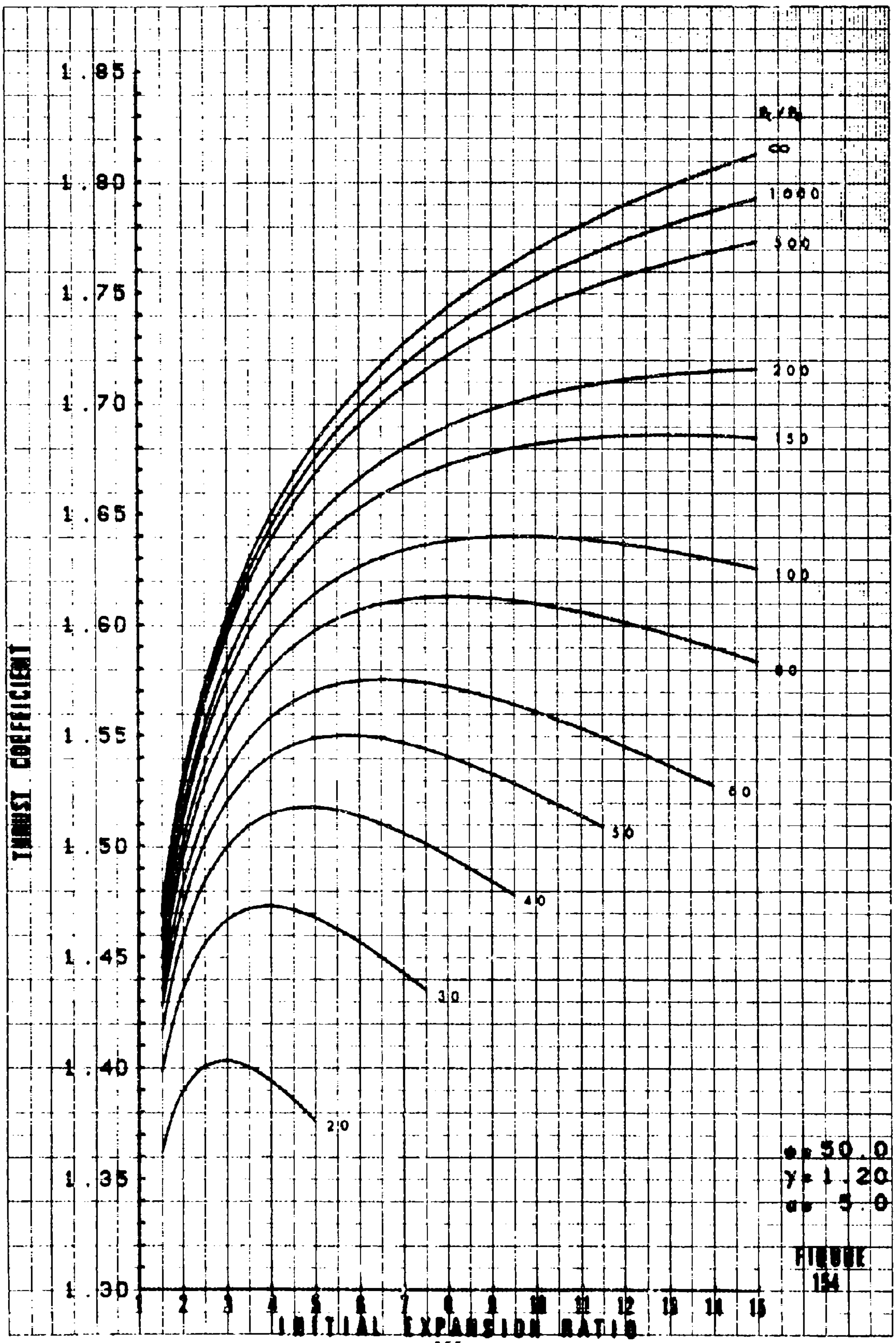

14.0
12.0
10.0
8.0
6.0
4.0
2.0
0
-2.0
-4.0
-6.0
-8.0
THRUST DEFLECTION ANGLE, DEGREES
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
INITIAL EXPANSION RATIO
P_c/P_a
∞
1000
500
200
100
80
60
50
40
30
20

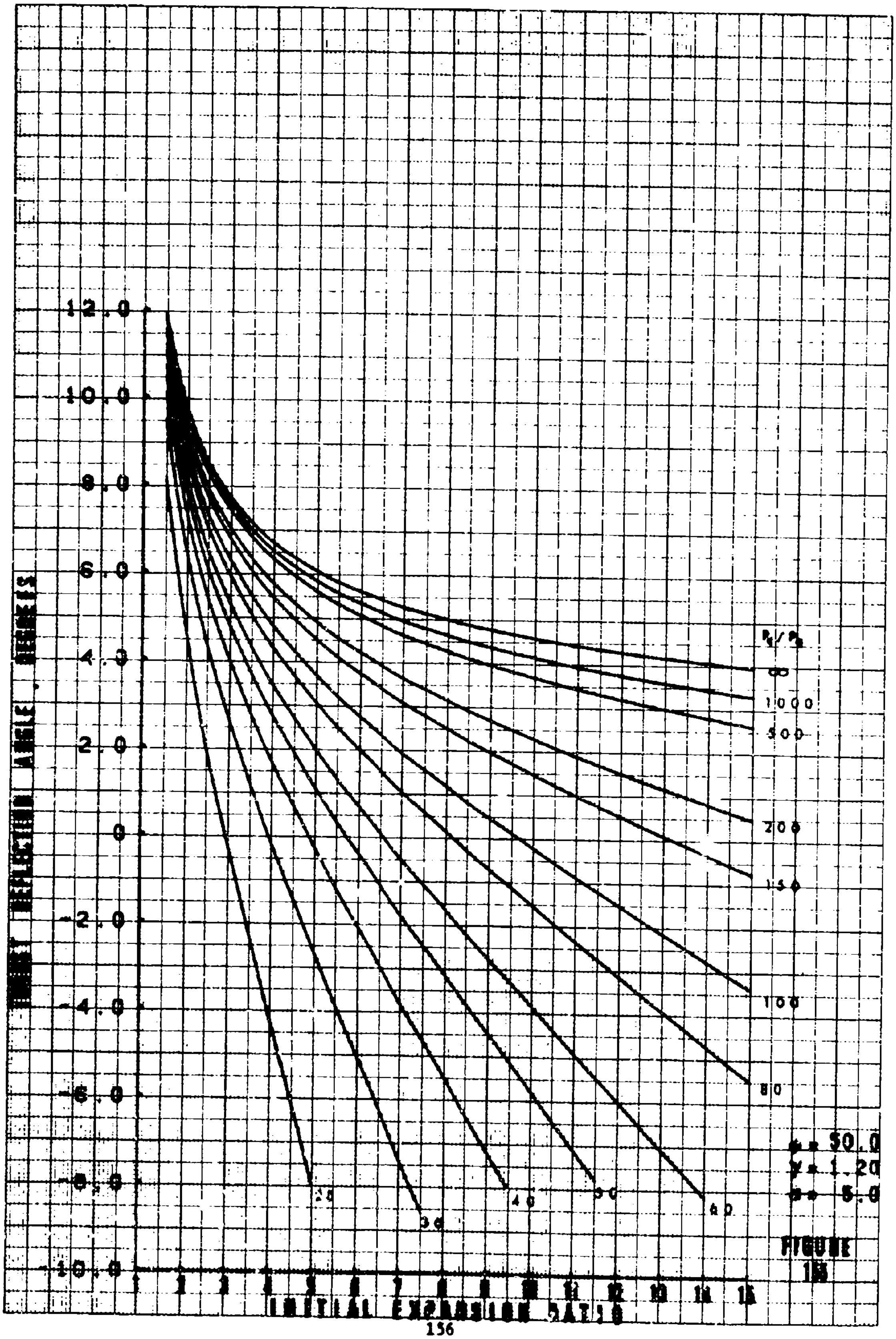
FIGURE 152

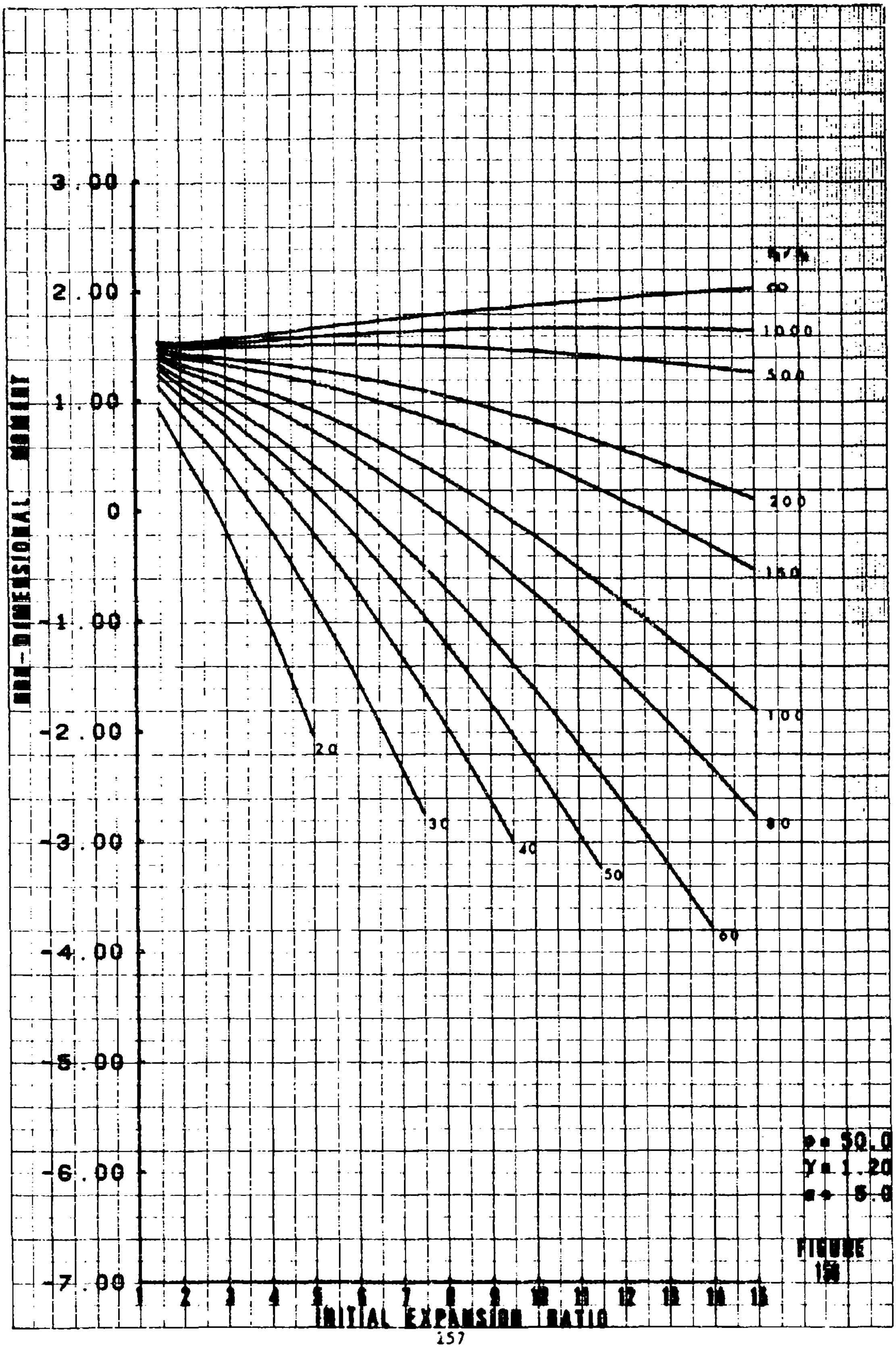

2.00
1.50
1.00
.50
0
-1.00
-1.50
-2.00
-2.50
1000
500
200
150
100
80
70
30
40
50
45.0
1.20
5.0
FIGURE
1
2
3
4
5
6
7
8
9
10



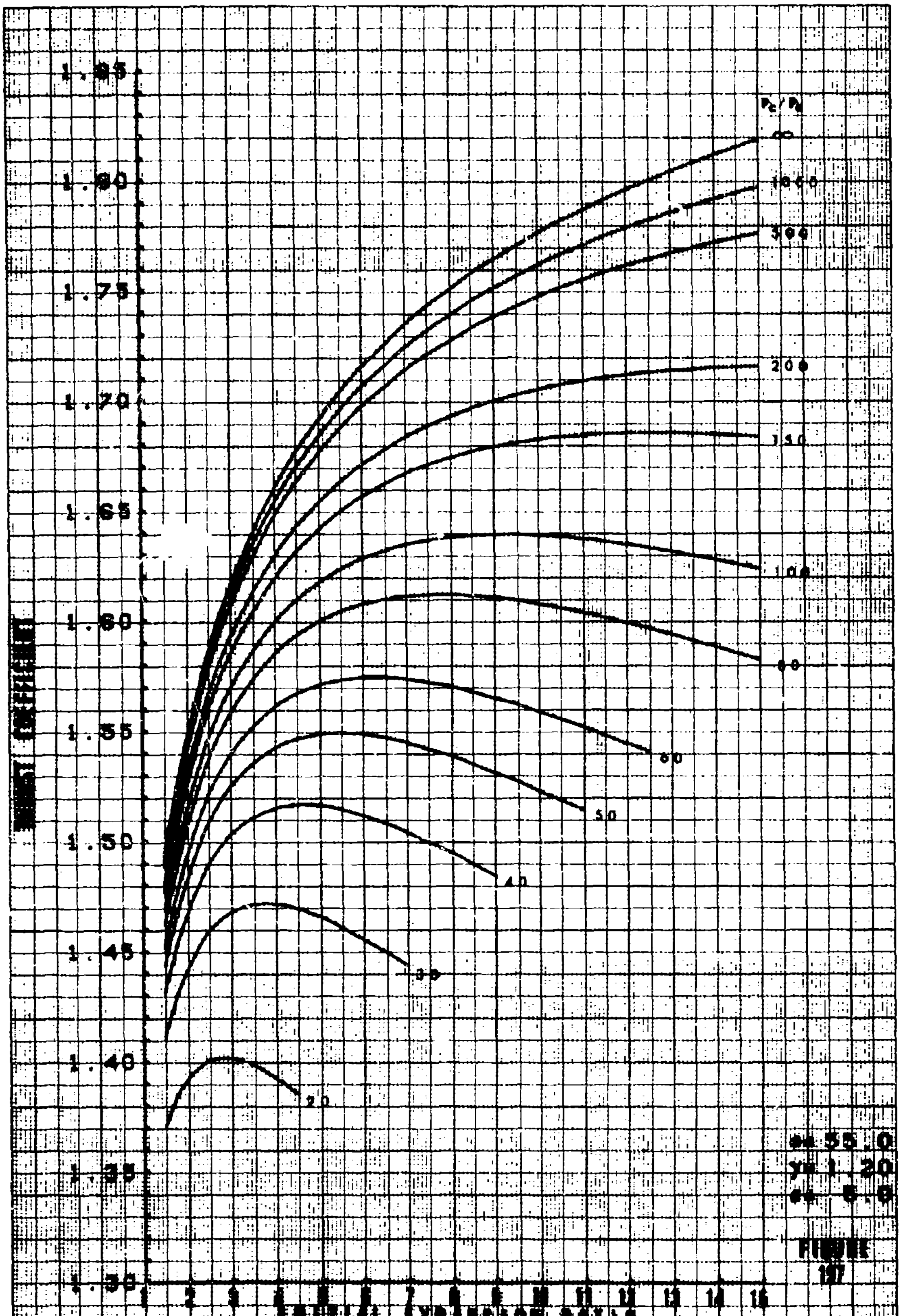
THRUST COEFFICIENT
INITIAL EXPANSION RATIO
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
∞
1000
500
200
150
100
80
60
50
40
30
20

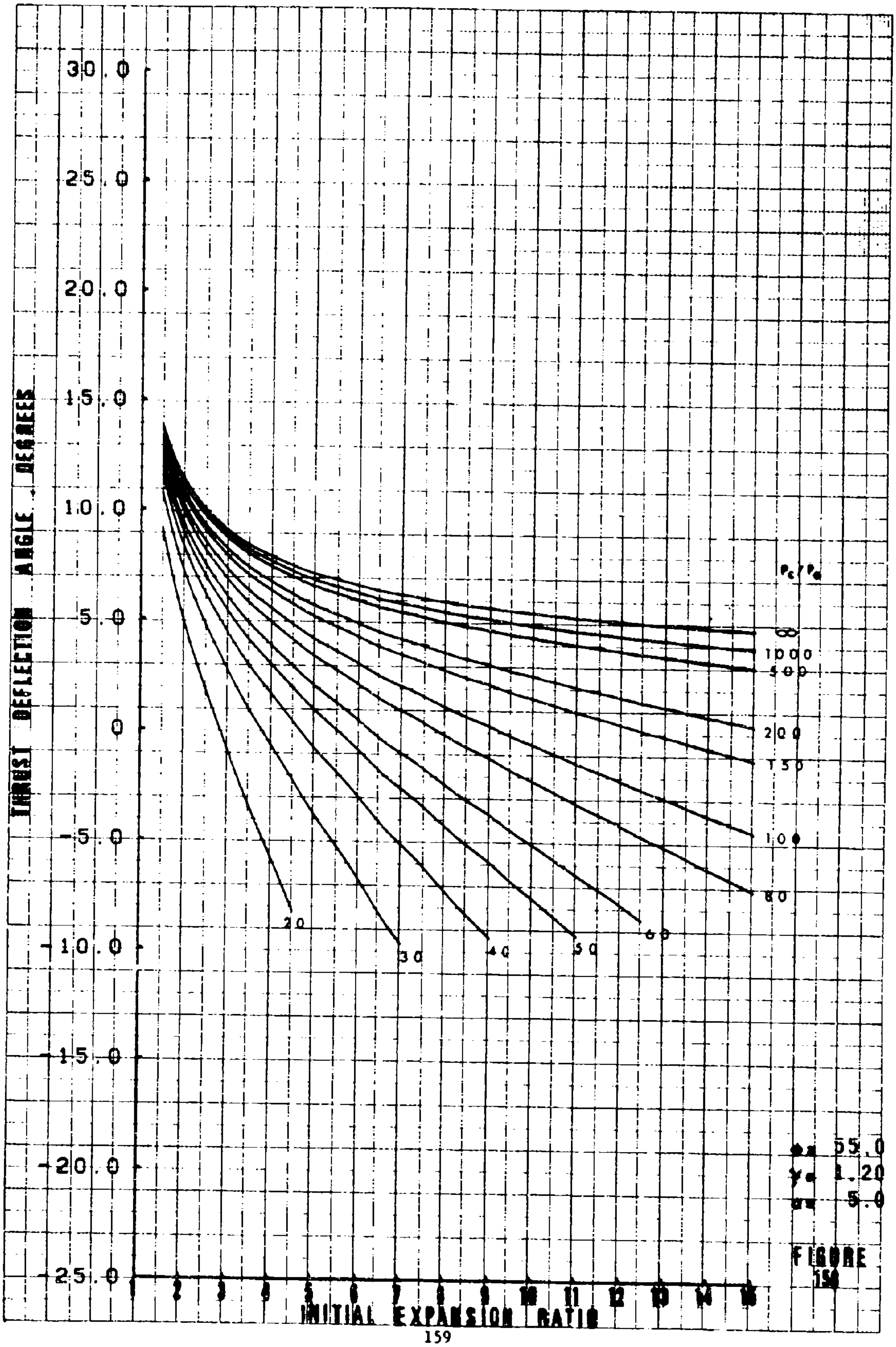
FIGURE 154

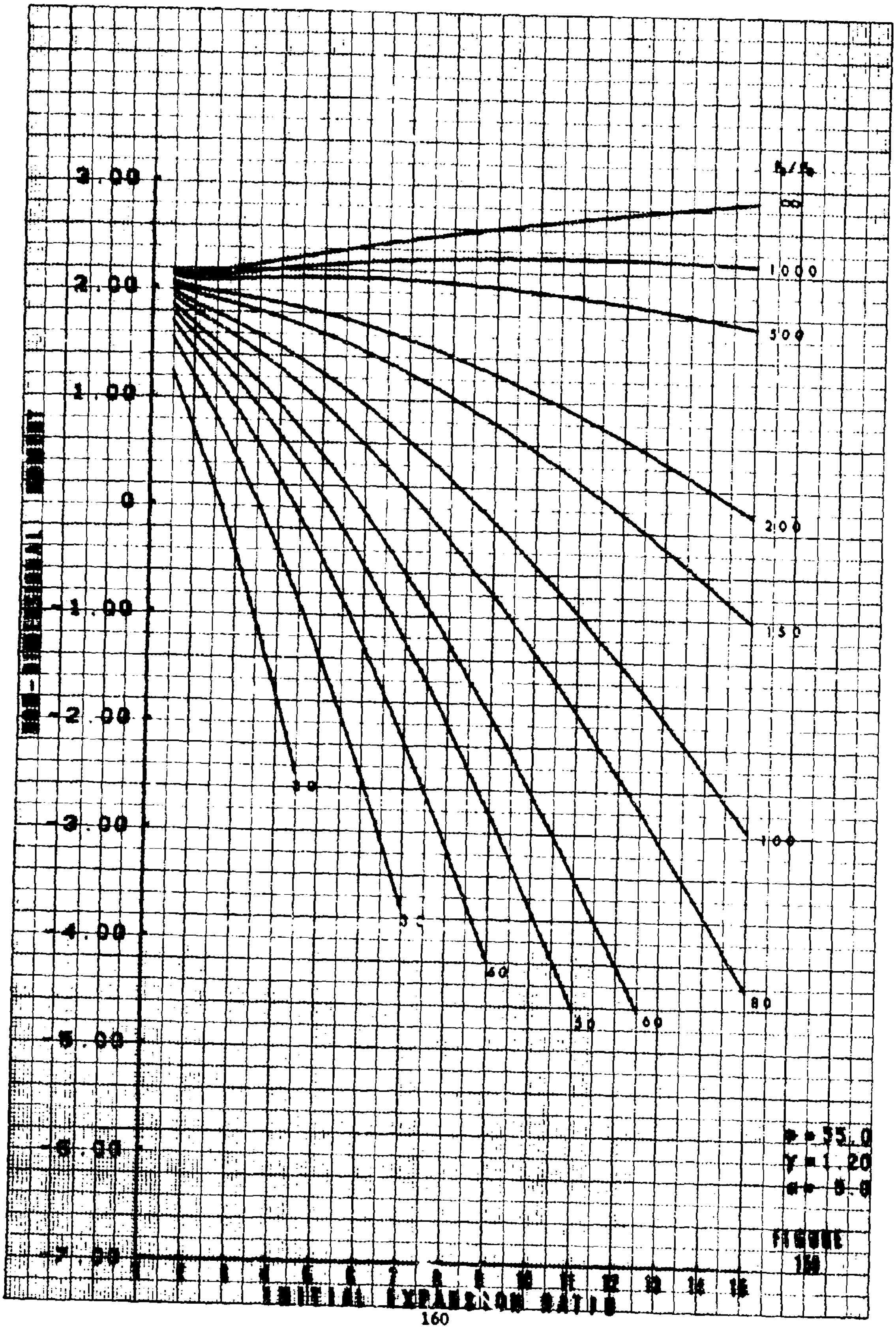

12.0
10.0
8.0
6.0
4.0
2.0
0
-2.0
-4.0
-6.0
-8.0
-10.0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
INITIAL EXPANSION RATIO
P_1/P_a
∞
1000
500
200
150
100
80
60
50
40
30
25
FIGURE
15

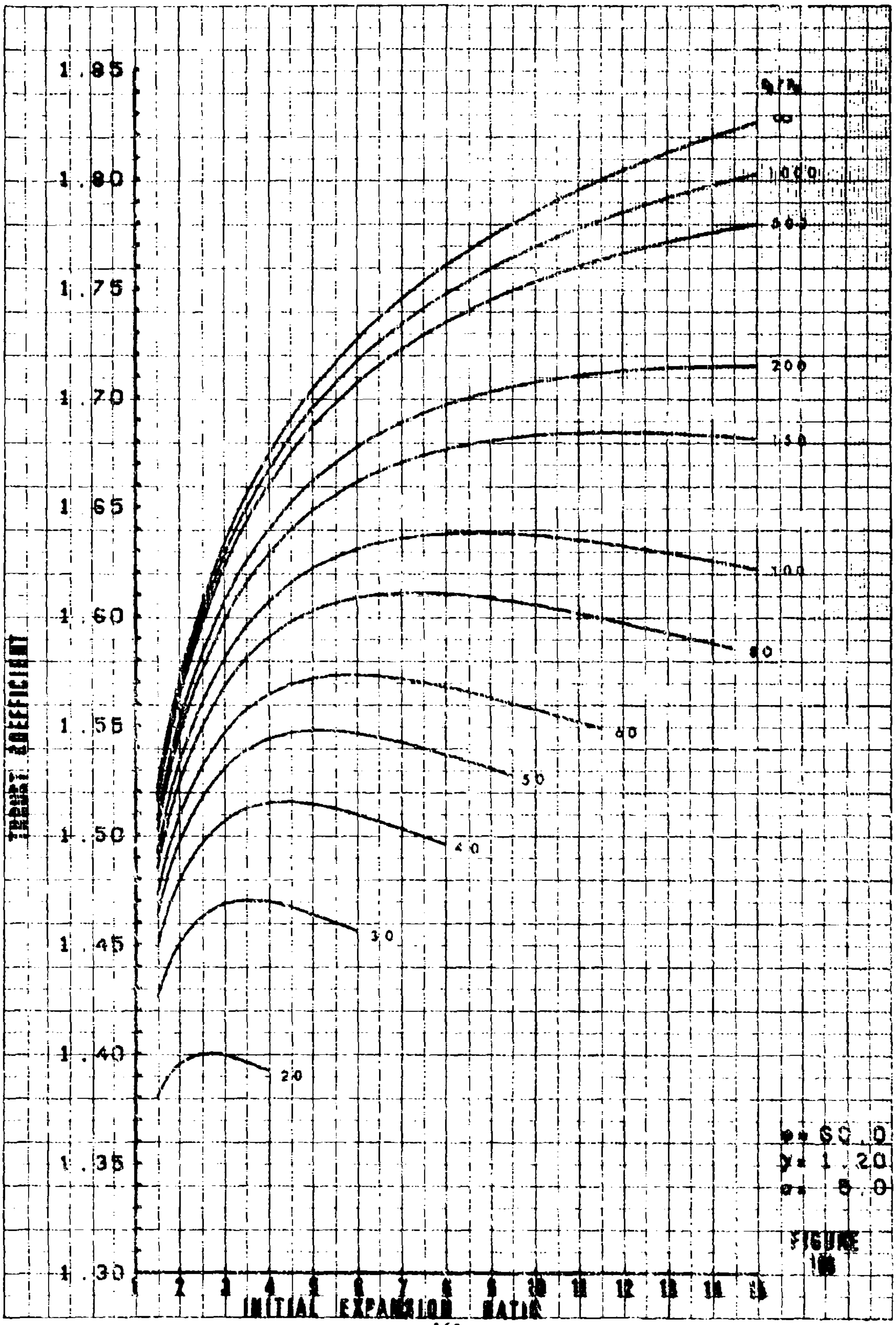


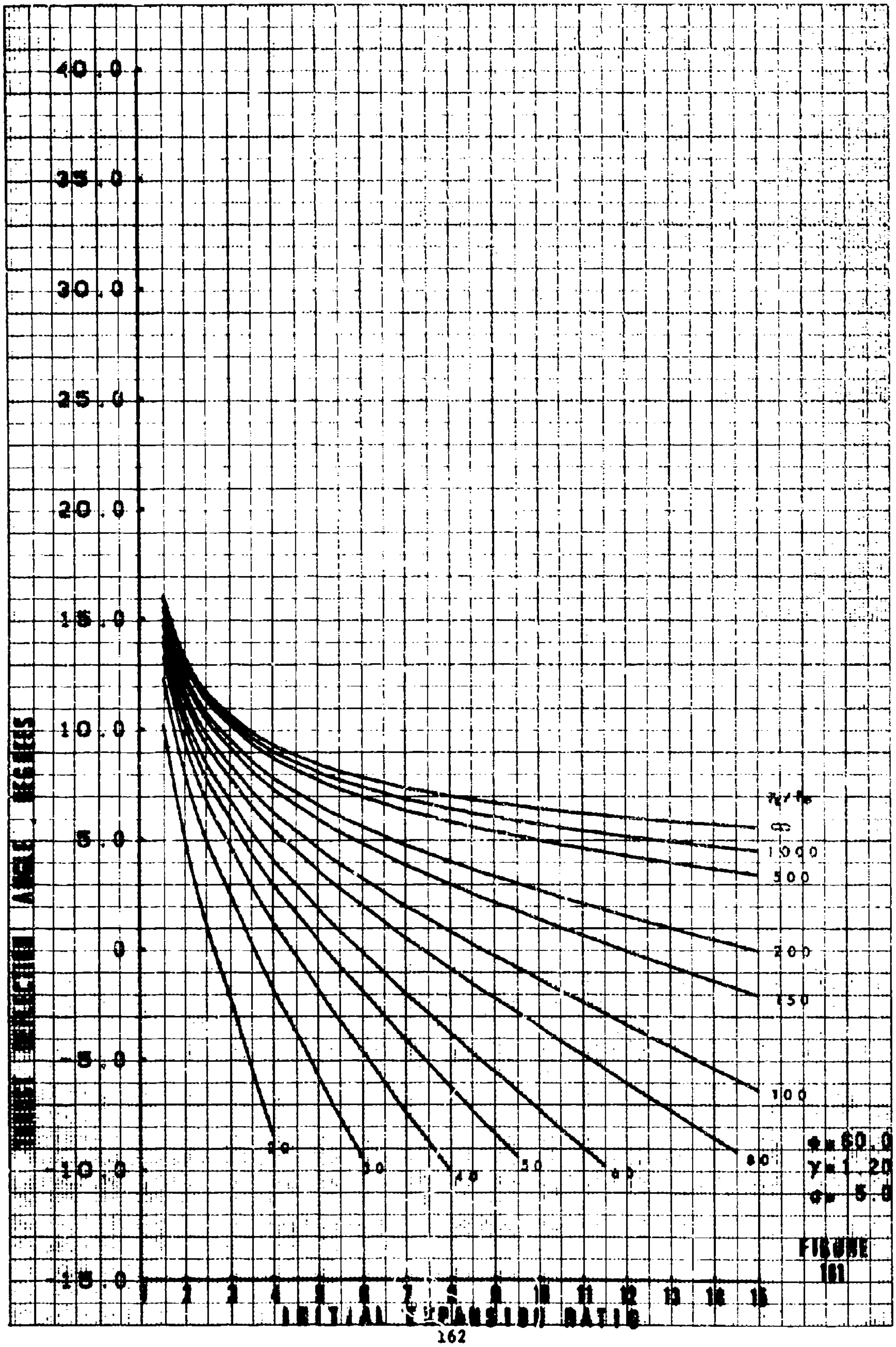
3.00
2.00
1.00
0
-1.00
-2.00
-3.00
-4.00
-5.00
-6.00
-7.00
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
INITIAL EXPANSION RATIO
NON-DIMENSIONAL MOMENT
∞
1000
500
200
150
100
80
20
30
40
50
60
1.20


Pc/Pe
1000
500
200
150
100
80
60
50
40
30
20
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30

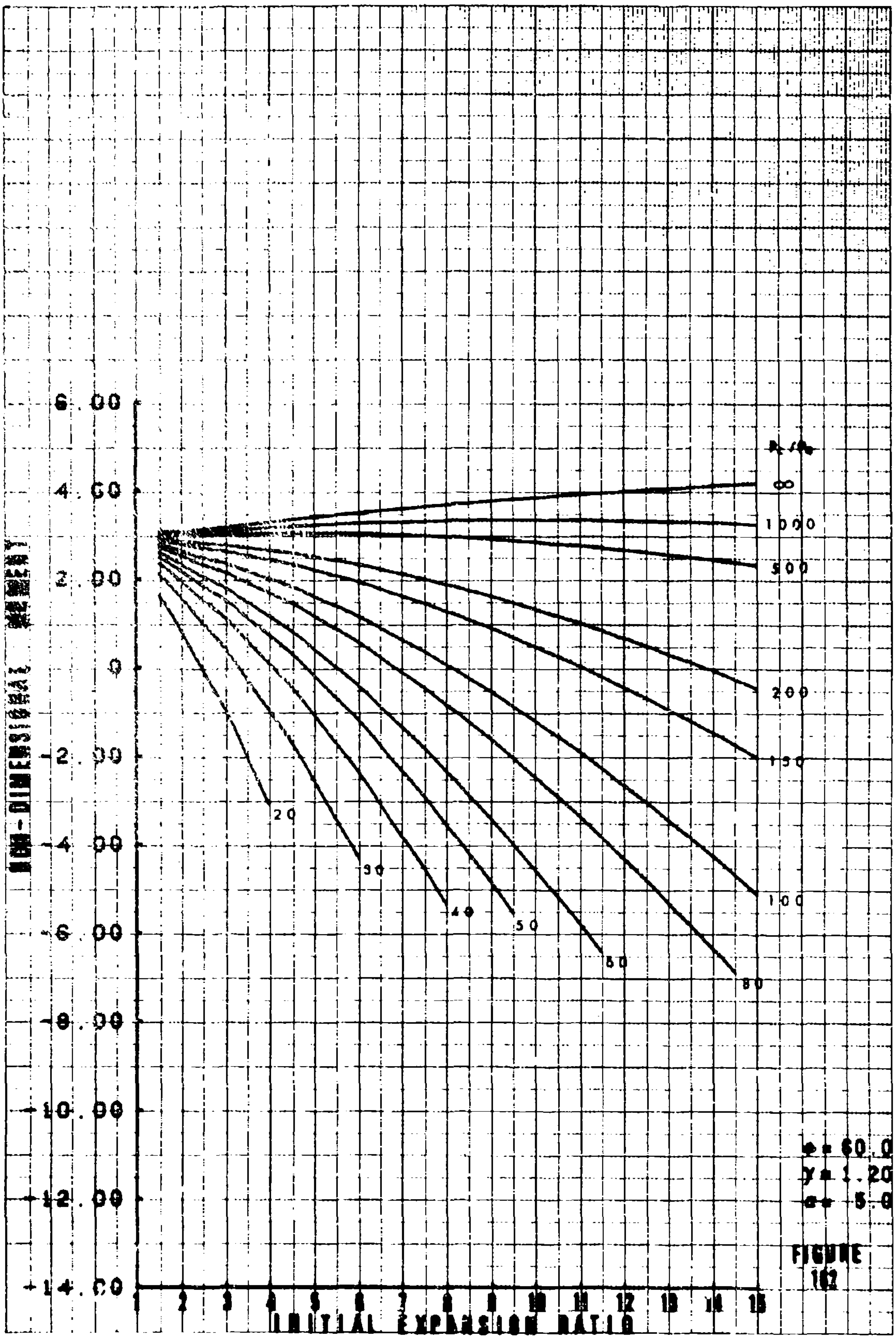

THRUST DEFLECTION ANGLE, DEGREES
30.0
25.0
20.0
15.0
10.0
5.0
0
-5.0
-10.0
-15.0
-20.0
-25.0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
∞
1000
500
200
150
100
80
60
50
40
30
20
55.0
1.20
5.0
FIGURE


3.00
2.00
1.00
0
-1.00
-2.00
-3.00
-4.00
-5.00
-6.00
-7.00
1000
500
200
150
100
80
60
50
γ = 1.20

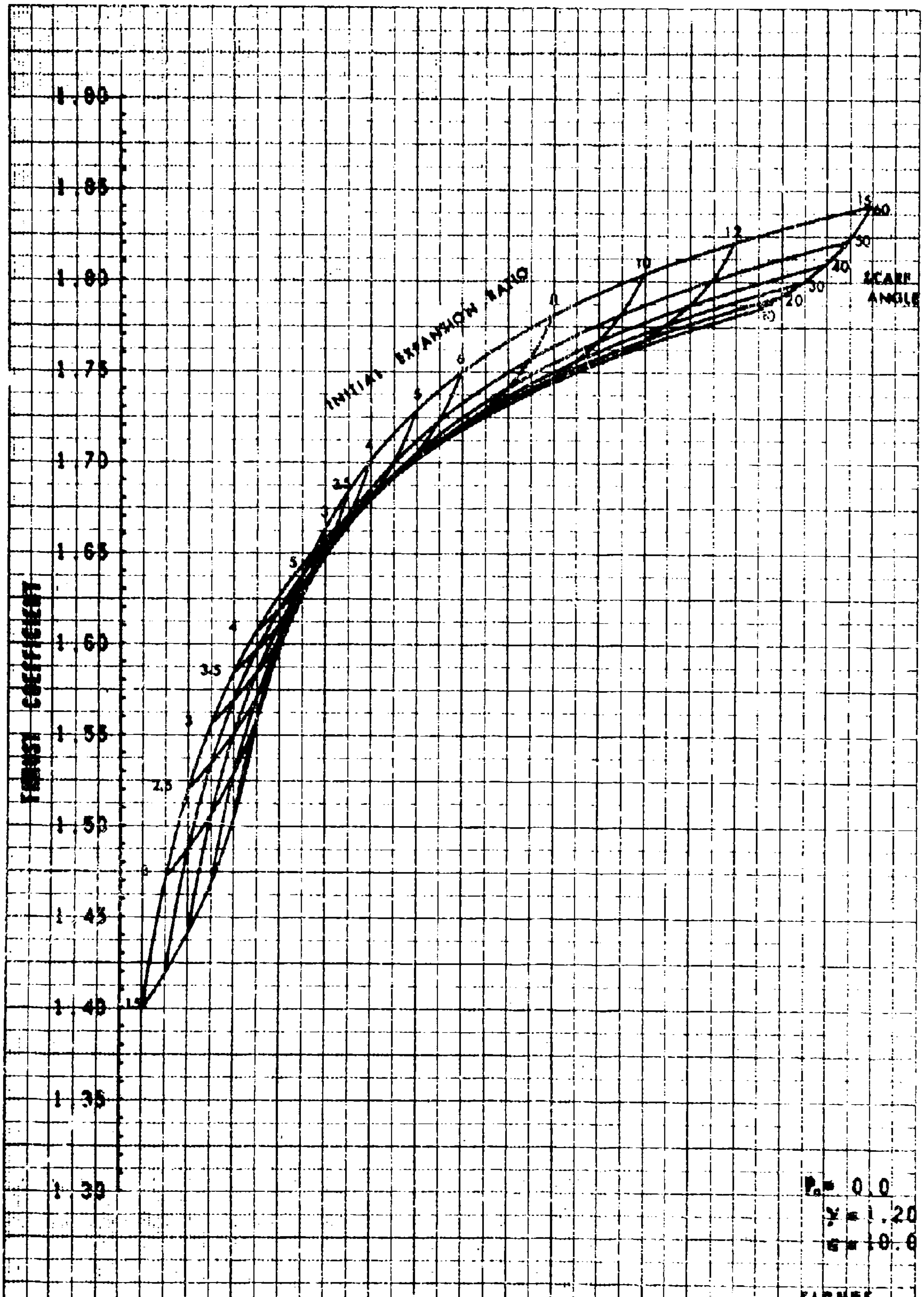

1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
THRUST COEFFICIENT
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
INITIAL EXPANSION RATIO
1000
500
200
150
100
80
60
50
40
30
20
FIGURE



40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0
-5.0
-10.0
-15.0
ANGLE
∞
1000
500
200
150
100
80
20
30
40
50
60
γ = 1.20
FIGURE



6.00
4.00
2.00
0
-2.00
-4.00
-6.00
-8.00
-10.00
-12.00
-14.00
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
∞
1000
500
200
150
100
80
60
50
40
30
20
φ = 60.0
γ = 1.20
α = 5.0
FIGURE 162


THRUST COEFFICIENT
1.90
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
INITIAL EXPANSION RATIO
SCARF ANGLE
P_a = 0.0
γ = 1.20
ε = 10.0
FIGURE

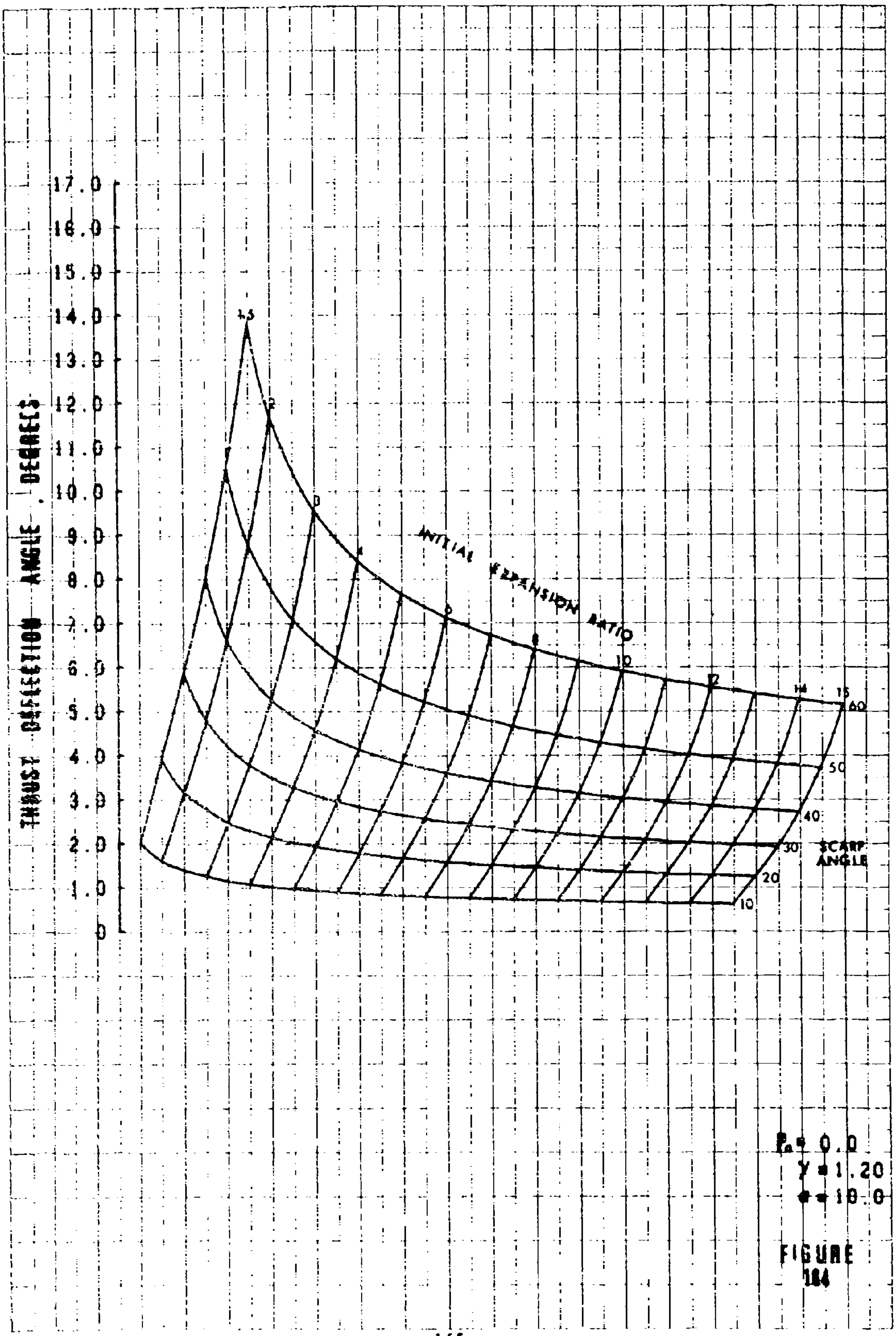
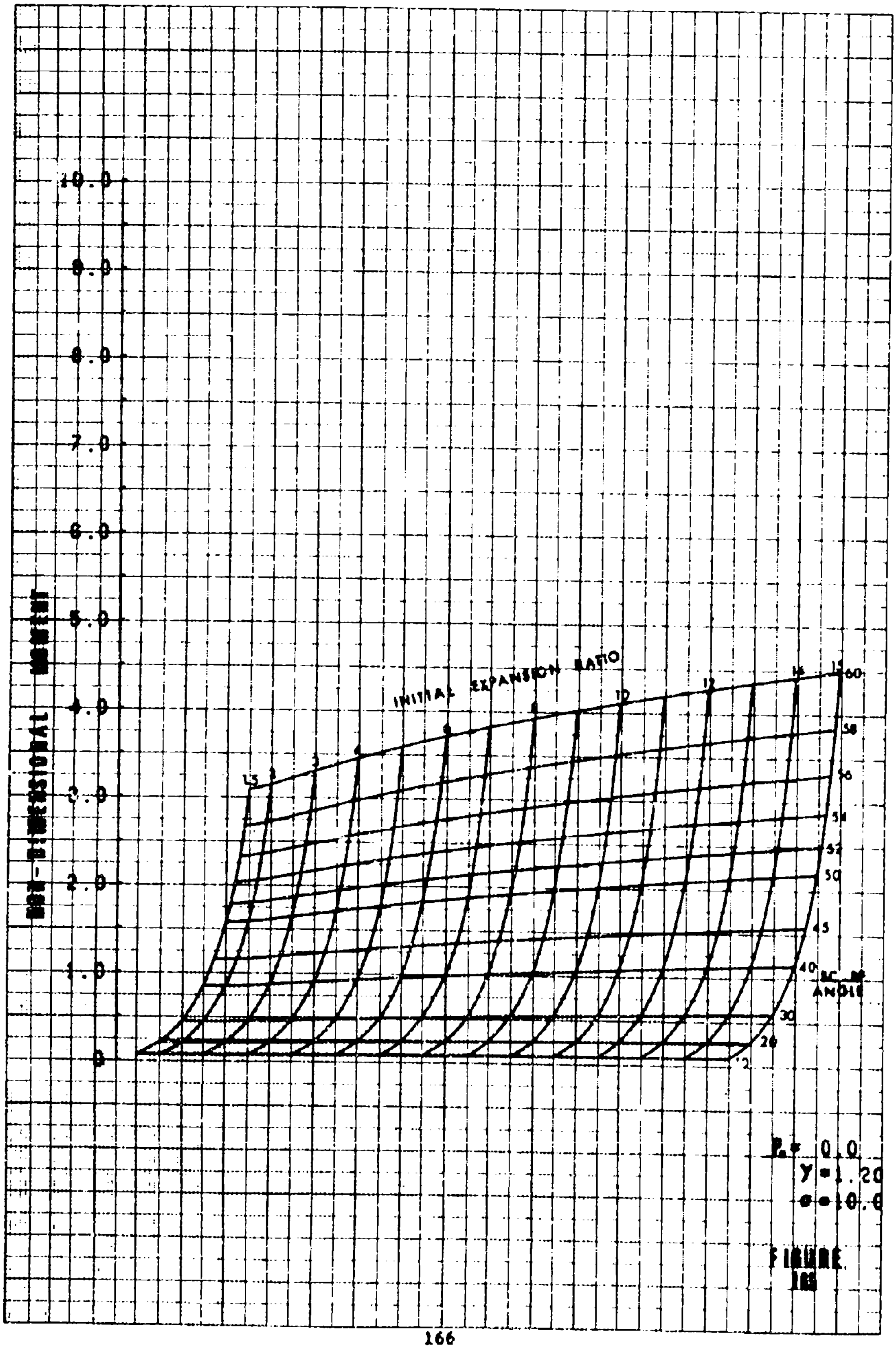
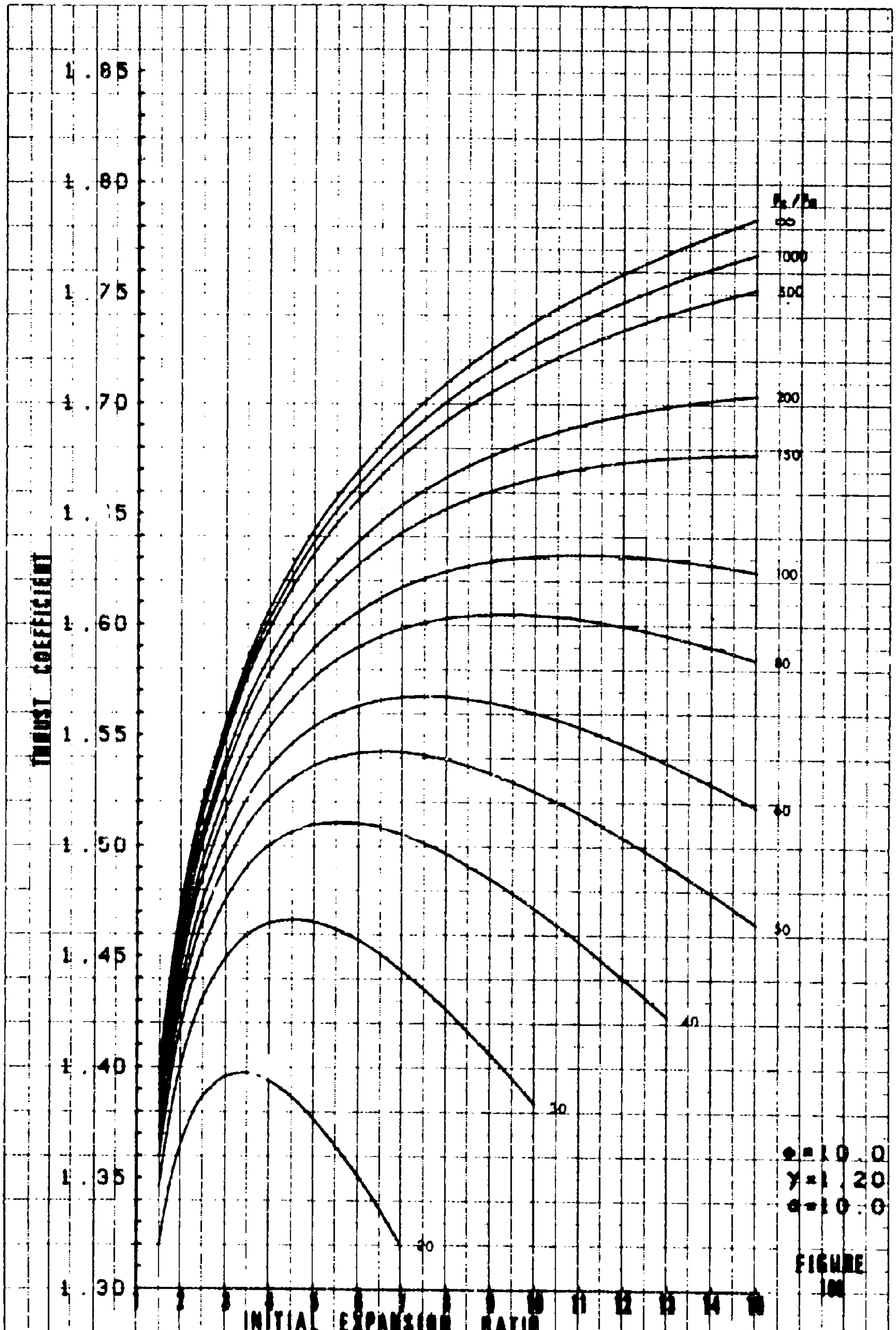

THRUST DEFLECTION ANGLE, DEGREES
17.0
16.0
15.0
14.0
13.0
12.0
11.0
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
INITIAL EXPANSION RATIO
1.5
2
3
4
6
8
10
12
14
15
60
50
40
30
20
10
SCARF ANGLE
P_a = 0.0
γ = 1.20
ϕ = 10.0

FIGURE 164


INITIAL EXPANSION RATIO
10.0
7.0
6.0
5.0
4.0
2.0
1.0
0
1.5
3
4
8
10
12
14
15
60
58
56
54
52
50
45
40
ANGLE
30
20
12



THRUST COEFFICIENT
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
INITIAL EXPANSION RATIO
2
3
4
5
6
7
8
9
10
11
12
13
14
15
1000
500
200
150
100
80
60
50
40
30
20
γ=1.20
FIGURE

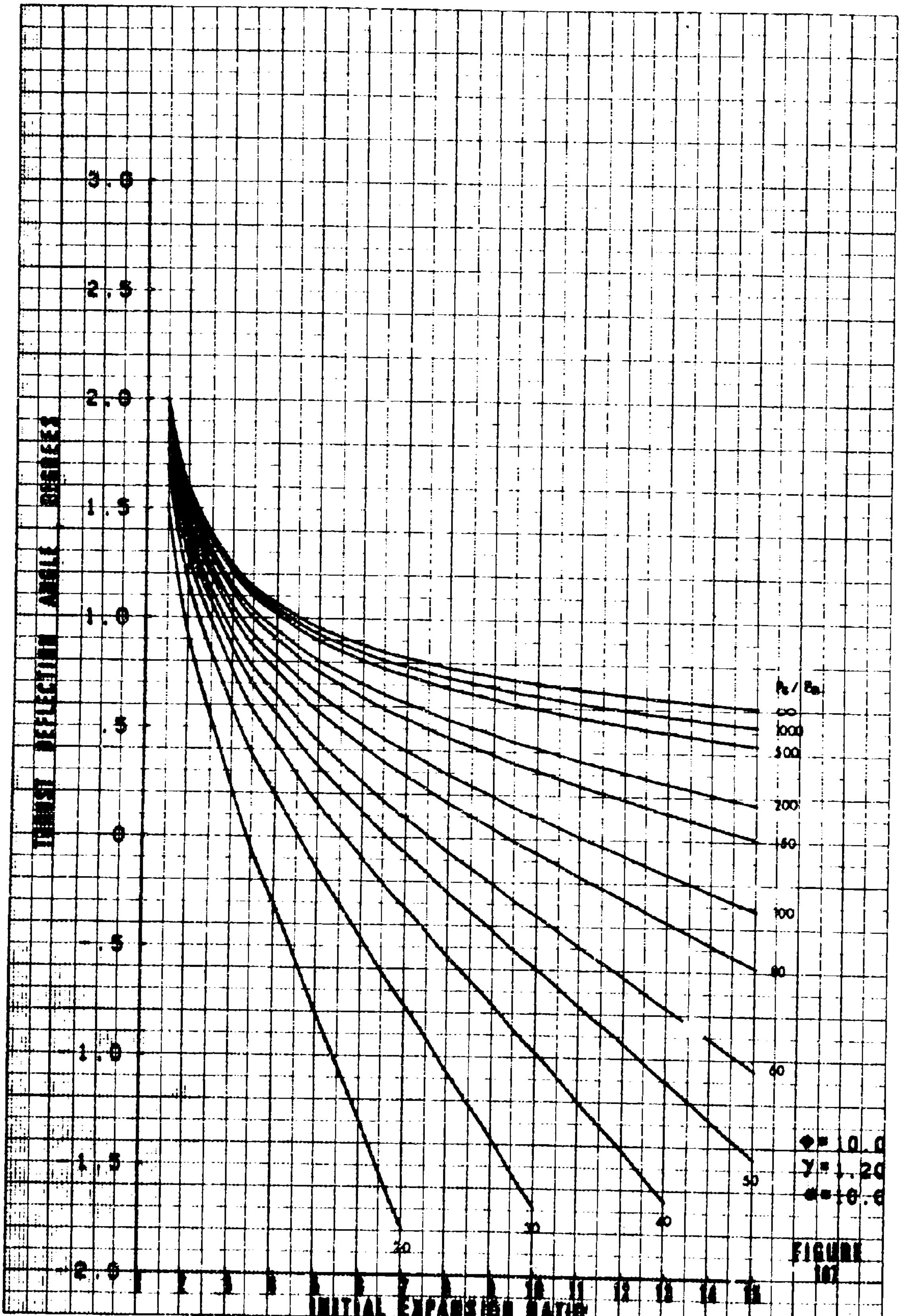
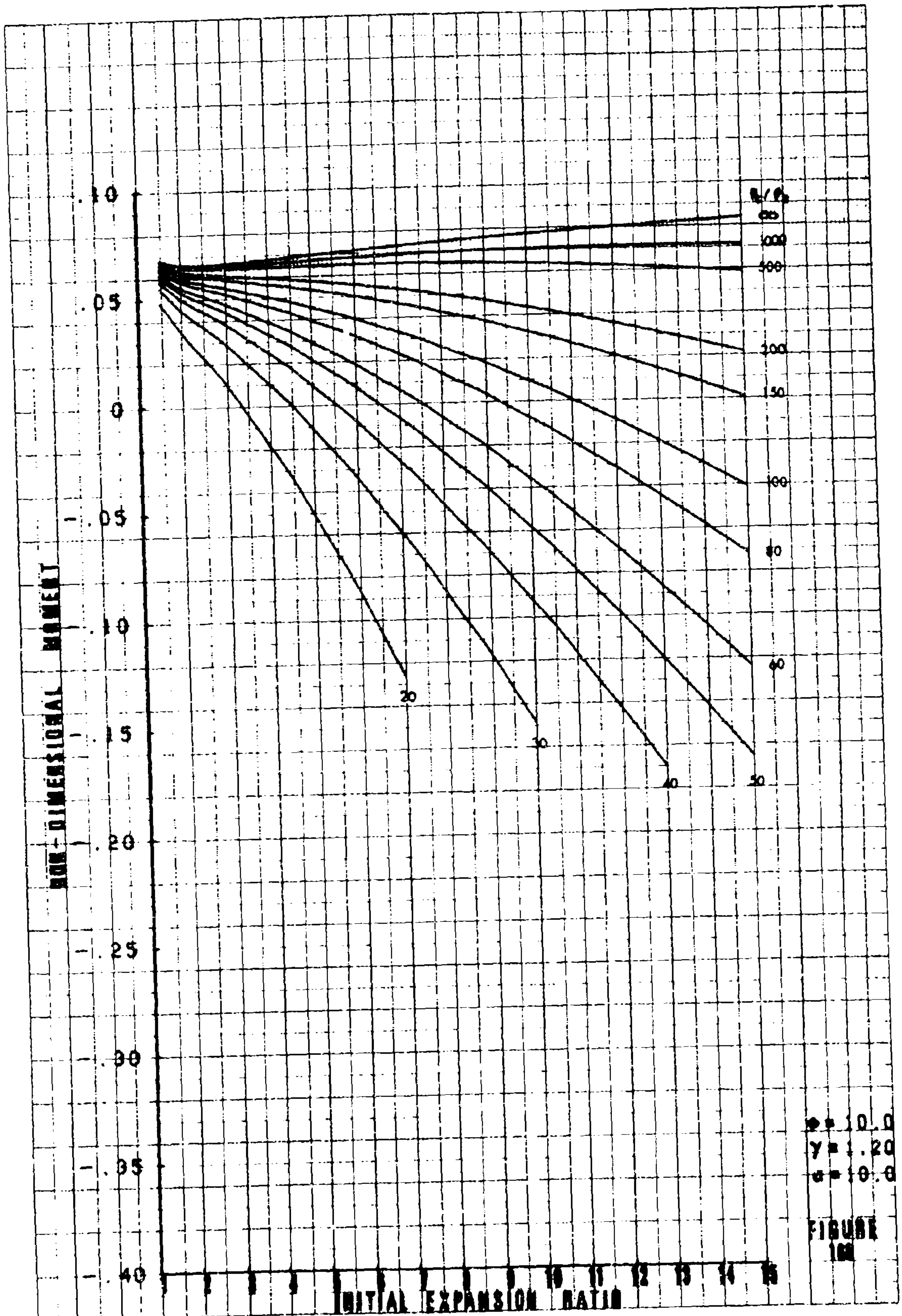
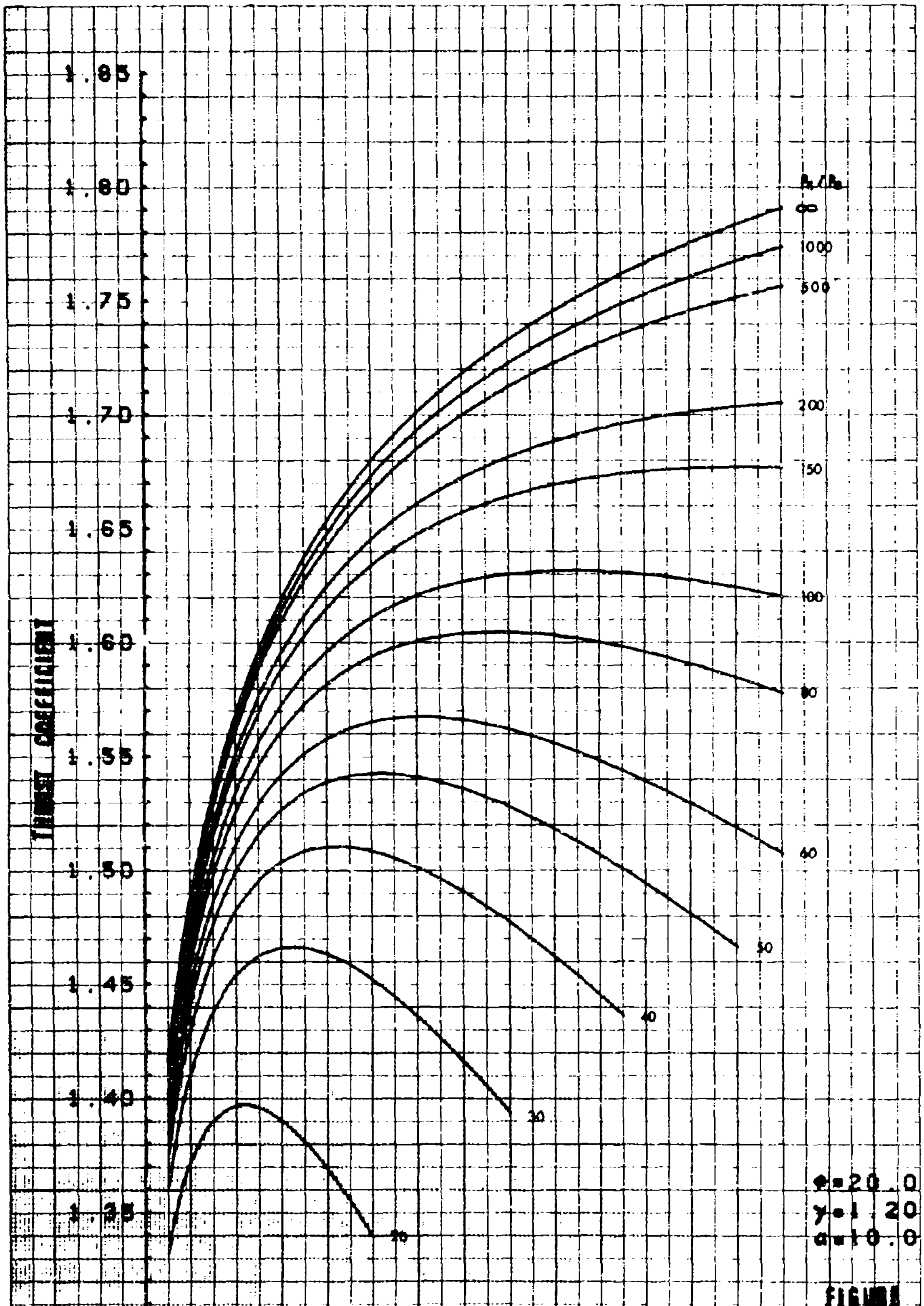

THRUST DEFLECTION ANGLE, DEGREES
3.0
2.5
2.0
1.5
1.0
.5
0
-.5
-1.0
-1.5
-2.0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
INITIAL EXPANSION RATIO
P_c / P_a
∞
1000
500
200
150
100
80
60
50
40
30
20
φ = 0.0
γ = 1.20
α = 0.6

FIGURE 107



NON-DIMENSIONAL MOMENT
.10
.05
0
-.05
-.10
-.15
-.20
-.25
-.30
-.35
-.40
INITIAL EXPANSION RATIO
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
∞
1000
500
200
150
100
80
60
50
40
30
20
γ = 1.20
FIGURE


1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
THRUST COEFFICIENT
P_c/P_a
∞
1000
500
200
150
100
80
60
50
40
30
20
Φ = 20.0
γ = 1.20
α = 10.0
FIGURE
INITIAL EXPANSION RATIO

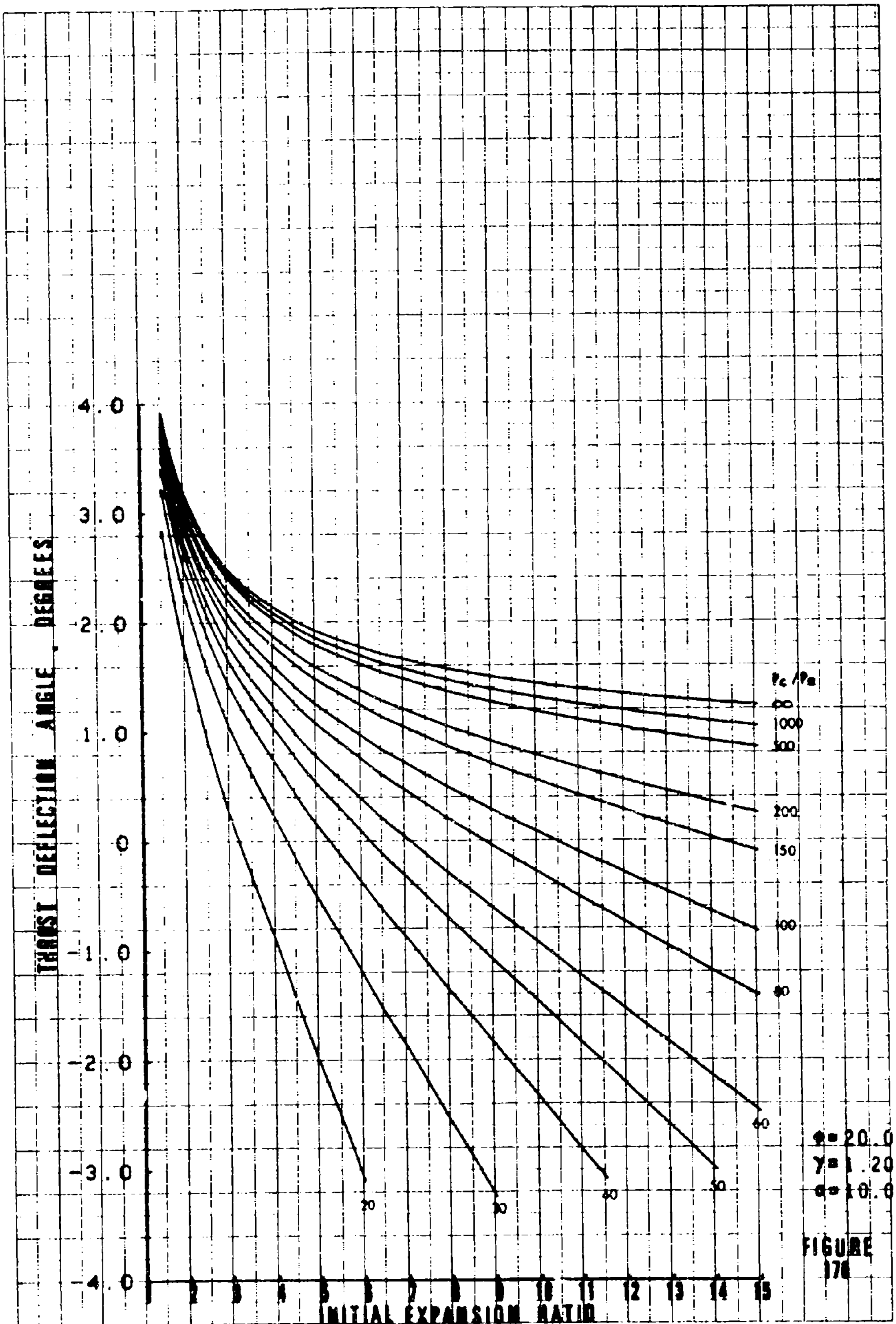
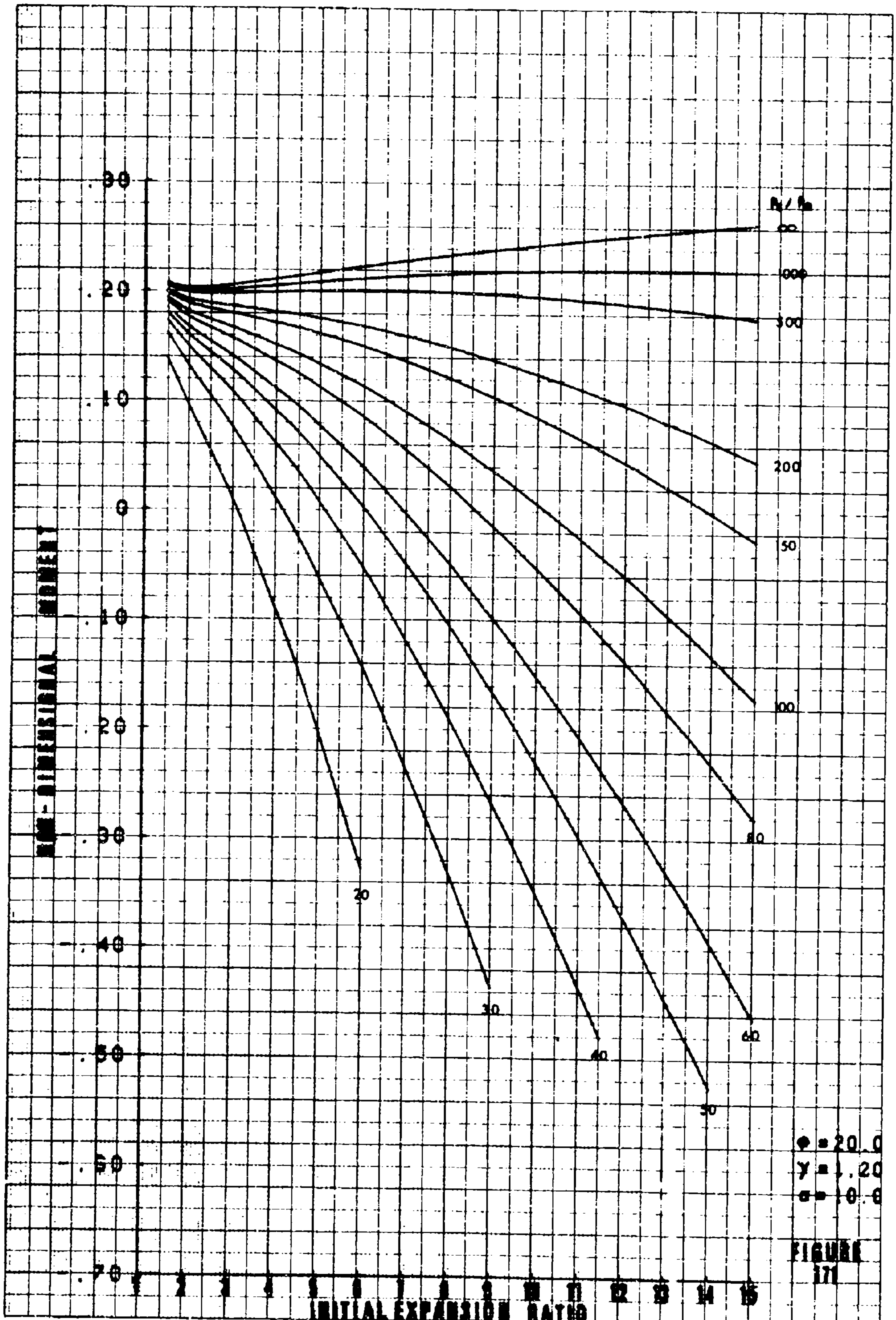
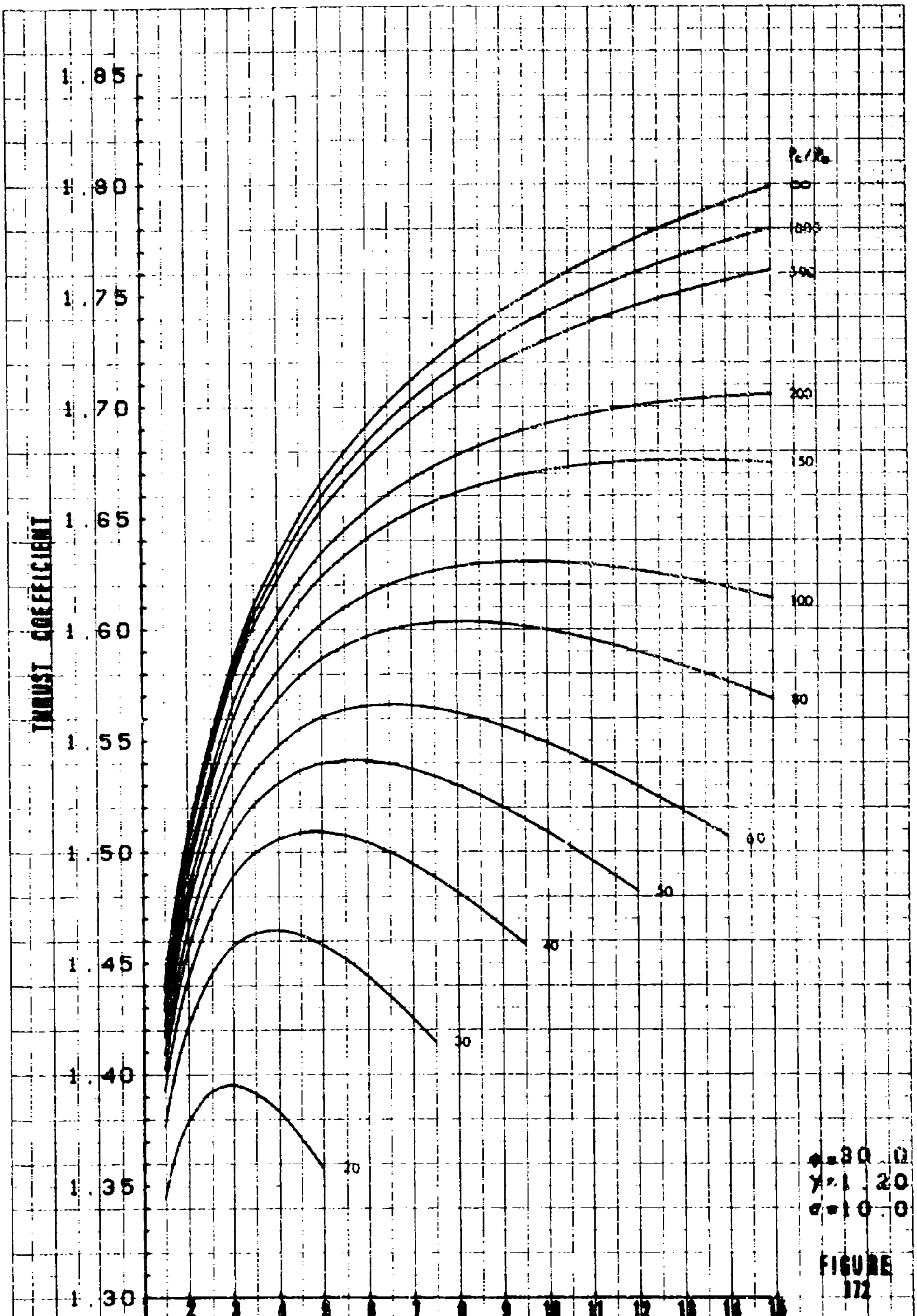

THRUST DEFLECTION ANGLE , DEGREES
INITIAL EXPANSION RATIO
4.0
3.0
2.0
1.0
0
-1.0
-2.0
-3.0
-4.0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
Pc/Pa
∞
1000
500
200
150
100
80
60
50
40
30
20
φ = 20.0
γ = 1.20
α = 10.0

FIGURE 178



.30
.20
.10
0
-.10
-.20
-.30
-.40
-.50
-.60
-.70
NON-DIMENSIONAL MOMENT
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
INITIAL EXPANSION RATIO
∞
1000
300
200
150
100
80
60
50
40
30
20
Φ = 20.0
γ = 1.20
σ = 0.0

FIGURE
171



$\phi = 30.0$
$\gamma = 1.20$
$\sigma = 10.0$

FIGURE 172

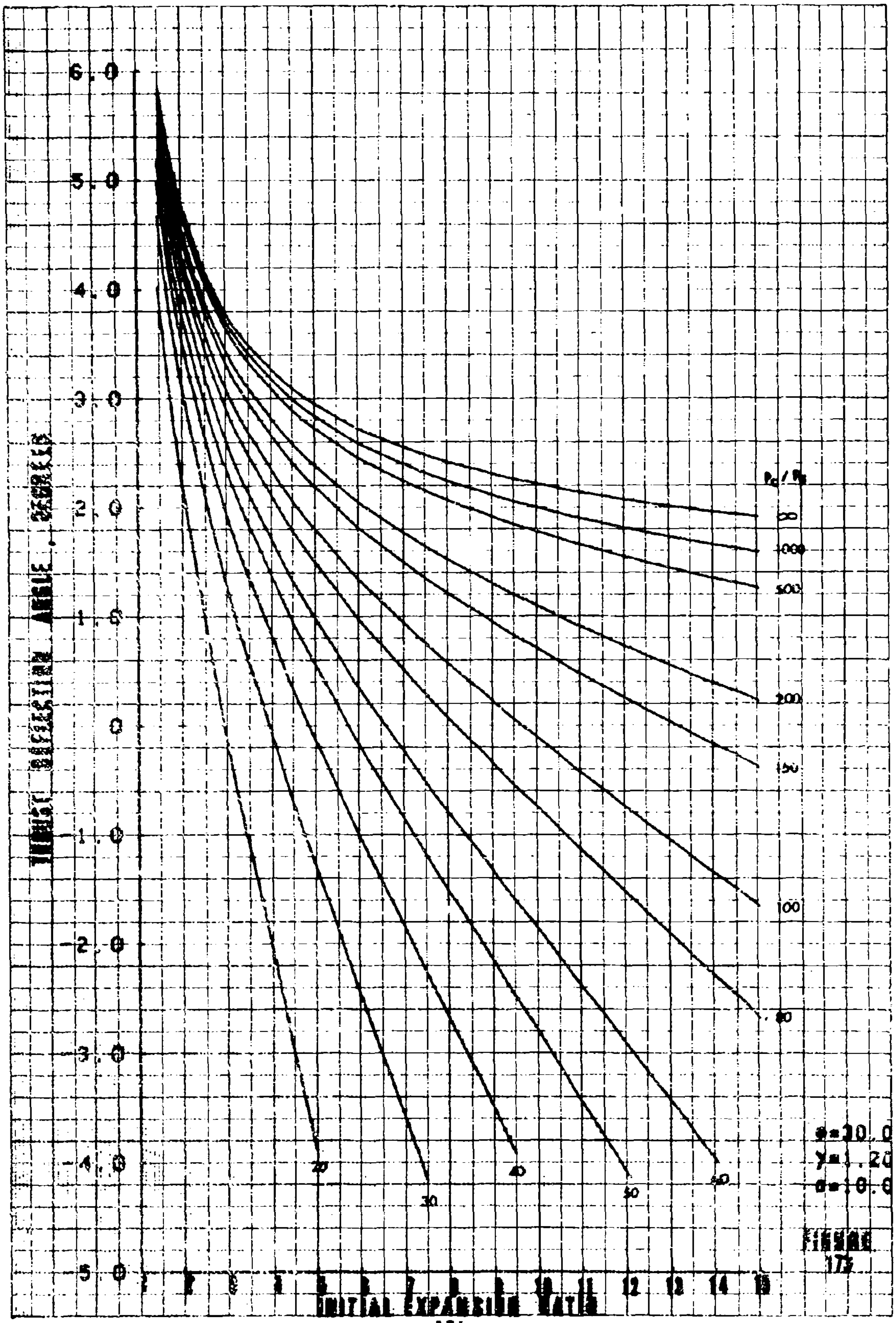
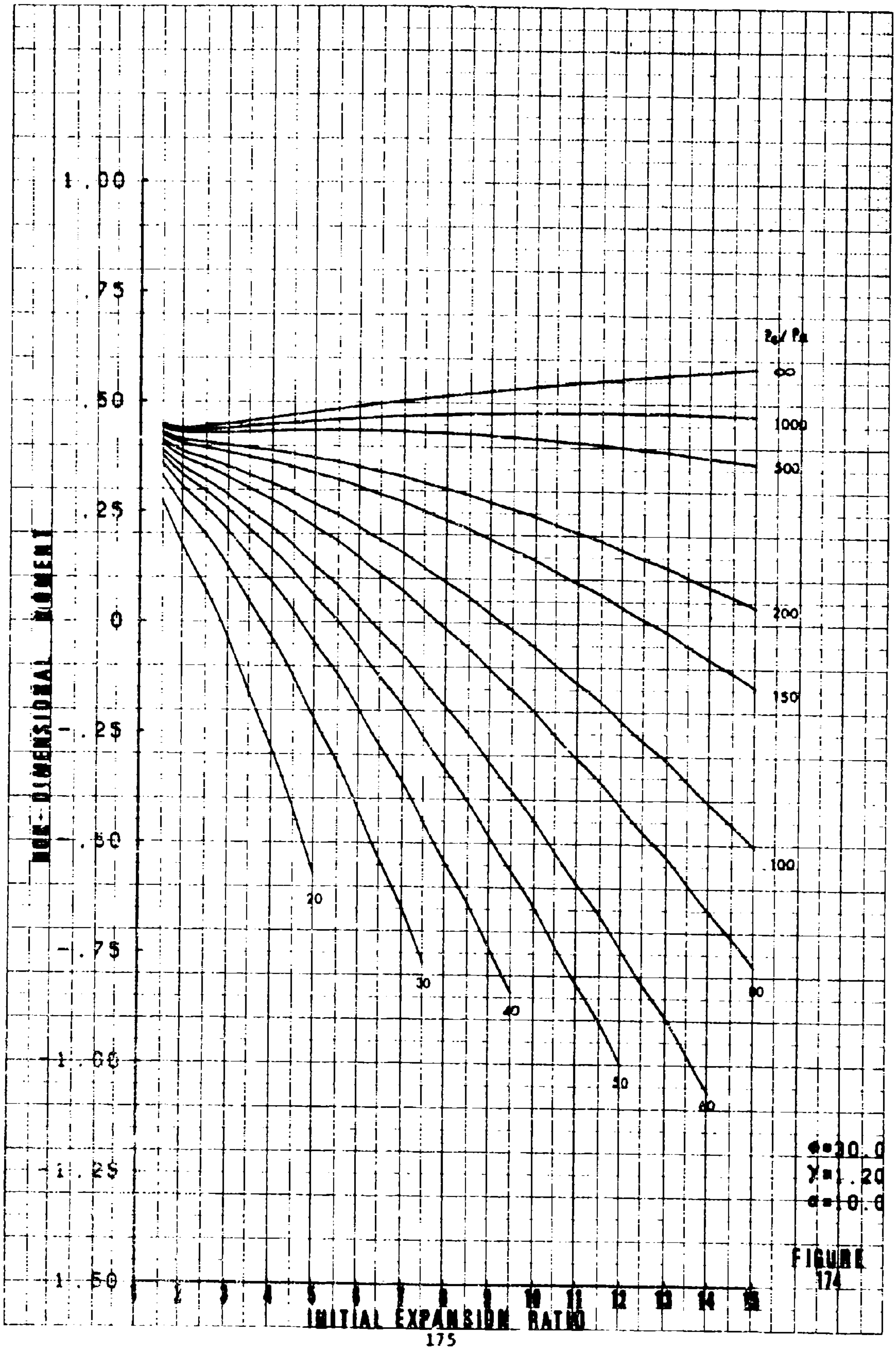
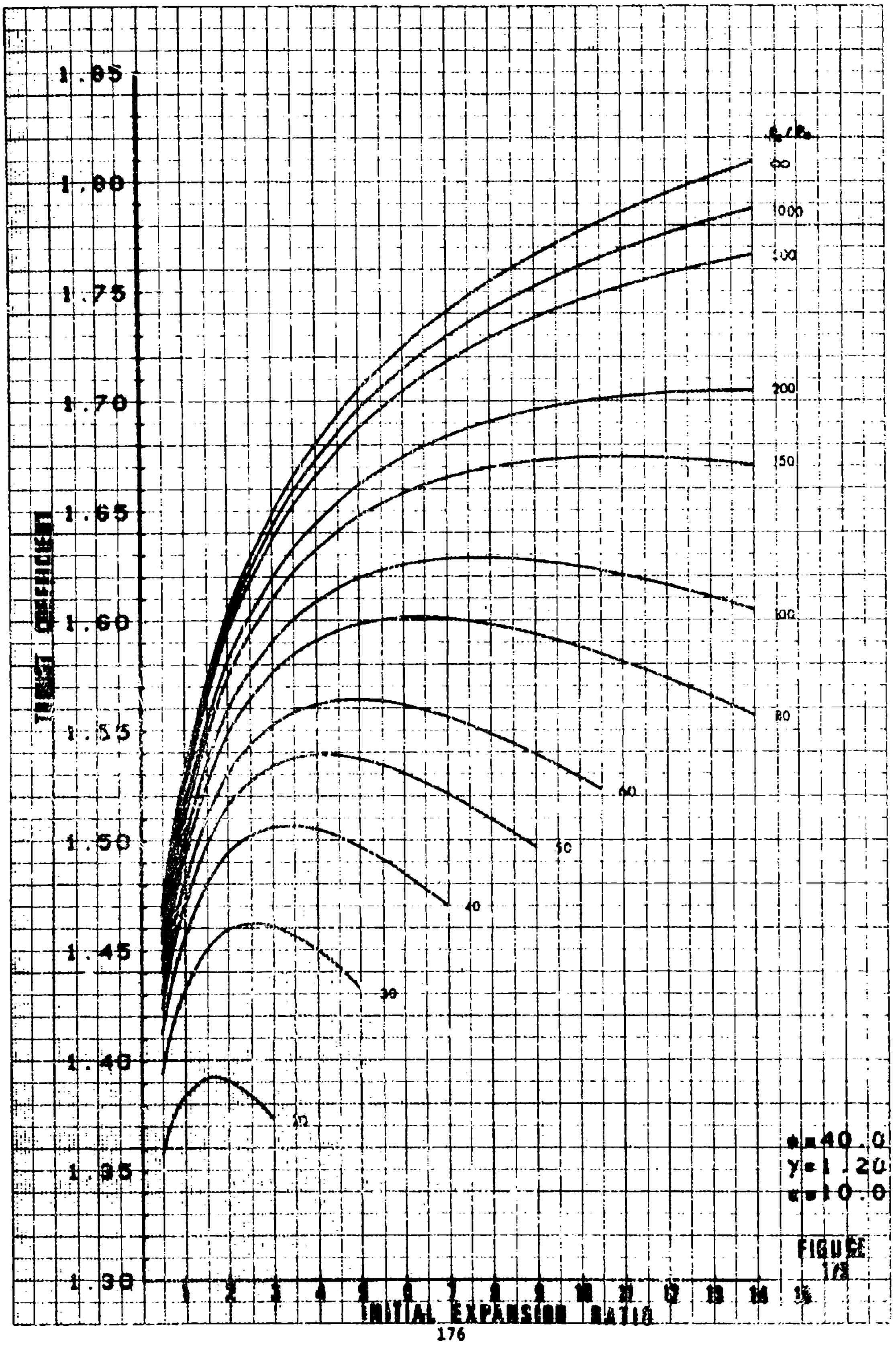

THRUST DEFLECTION ANGLE, DEGREES
INITIAL EXPANSION RATIO
6.0
5.0
4.0
3.0
2.0
1.0
0
-1.0
-2.0
-3.0
-4.0
-5.0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
Pc/Pa
∞
1000
500
200
150
100
80
60
50
40
30
20

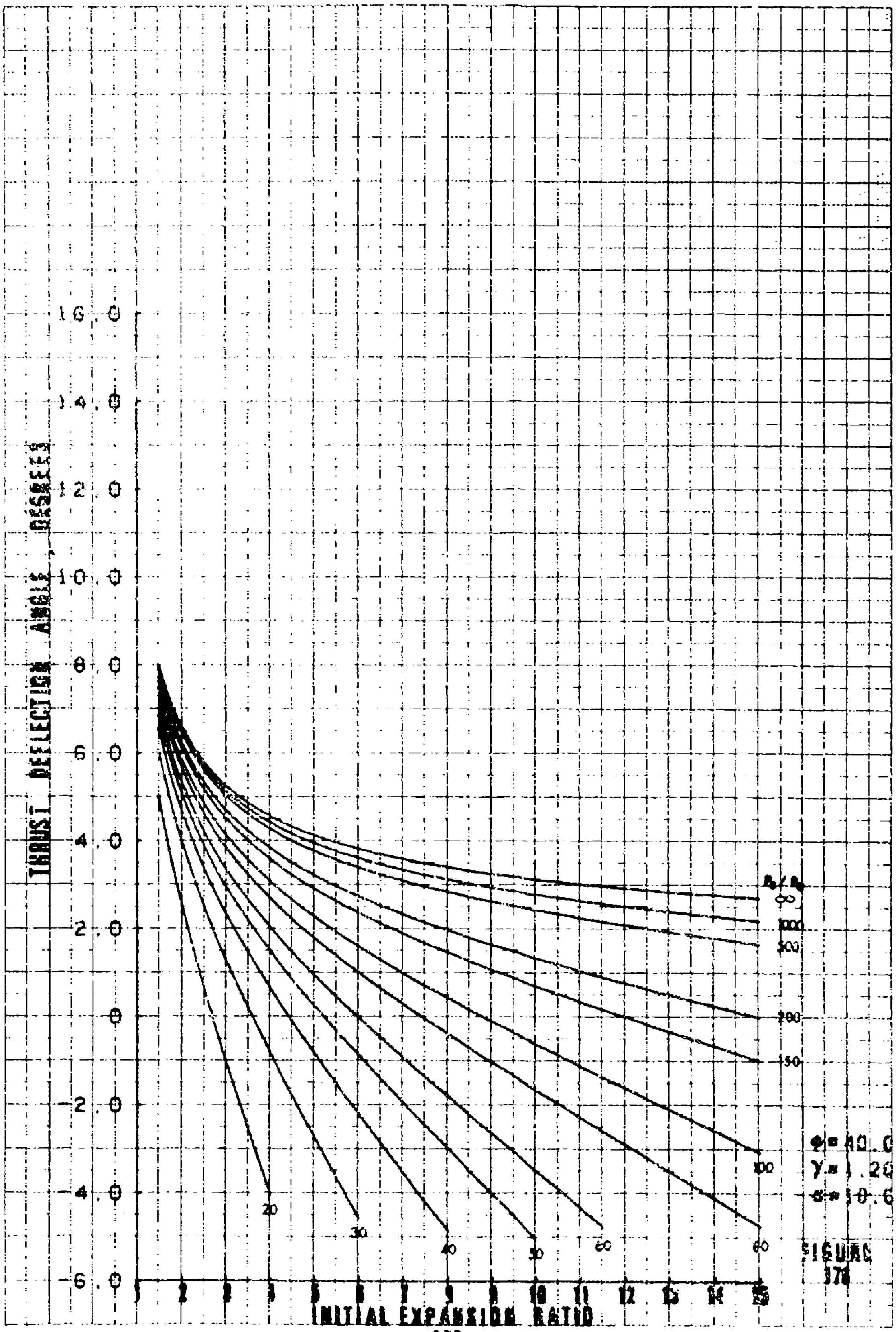
FIGURE 173



1.00
.75
.50
.25
0
-.25
-.50
-.75
-1.00
-1.25
-1.50
NON-DIMENSIONAL MOMENT
INITIAL EXPANSION RATIO
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
P_o/P_a
∞
1000
500
200
150
100
80
60
50
40
30
20

FIGURE 174


THRUST COEFFICIENT
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
P_c/P_e
∞
1000
500
200
150
100
80
60
50
40
30
20
$\phi = 40.0$
$\gamma = 1.20$
$\epsilon = 10.0$
FIGURE 178
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO


THRUST DEFLECTION ANGLE, DEGREES
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0
-2.0
-4.0
-6.0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
INITIAL EXPANSION RATIO
∞
1000
500
200
150
100
80
60
50
40
30
20

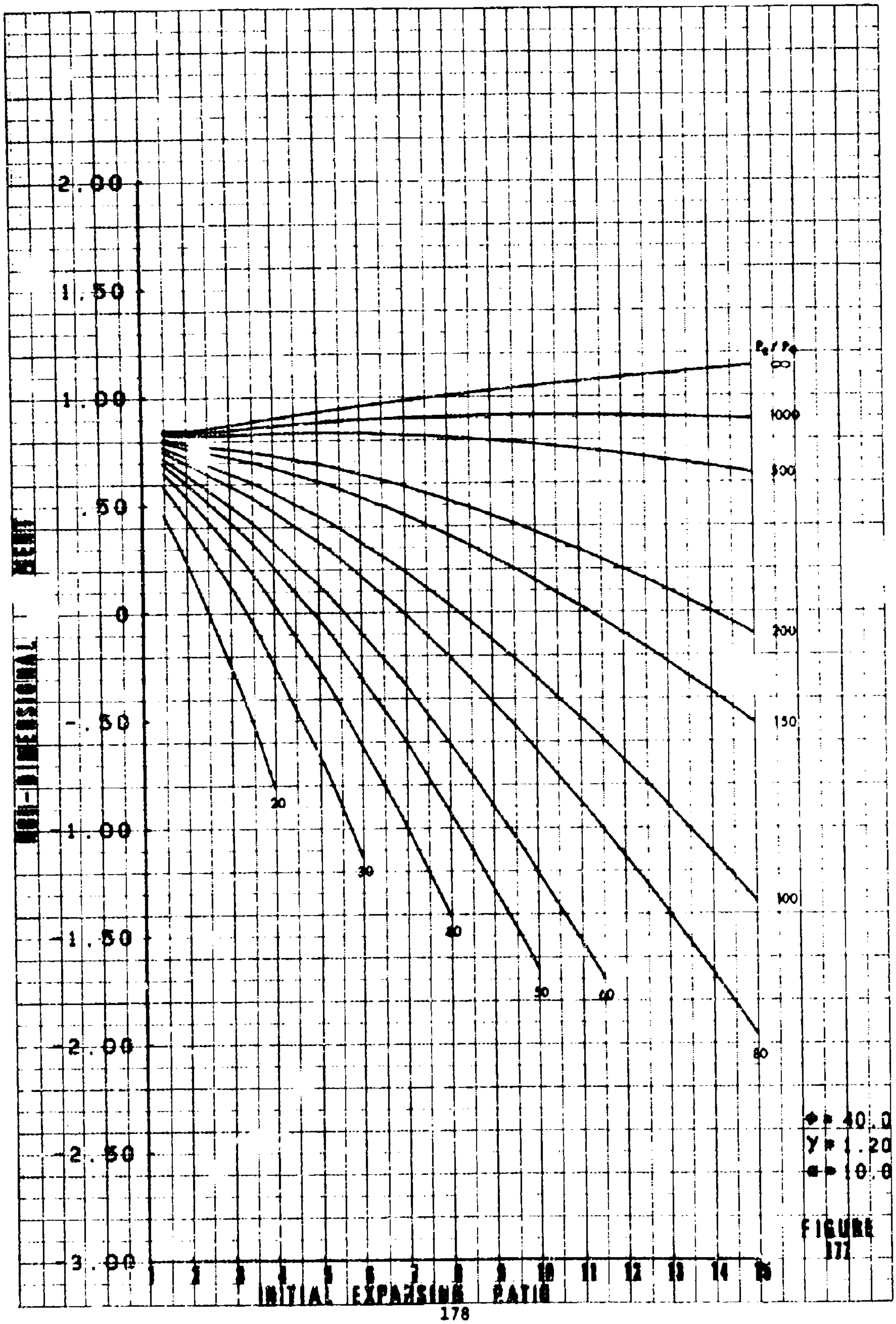
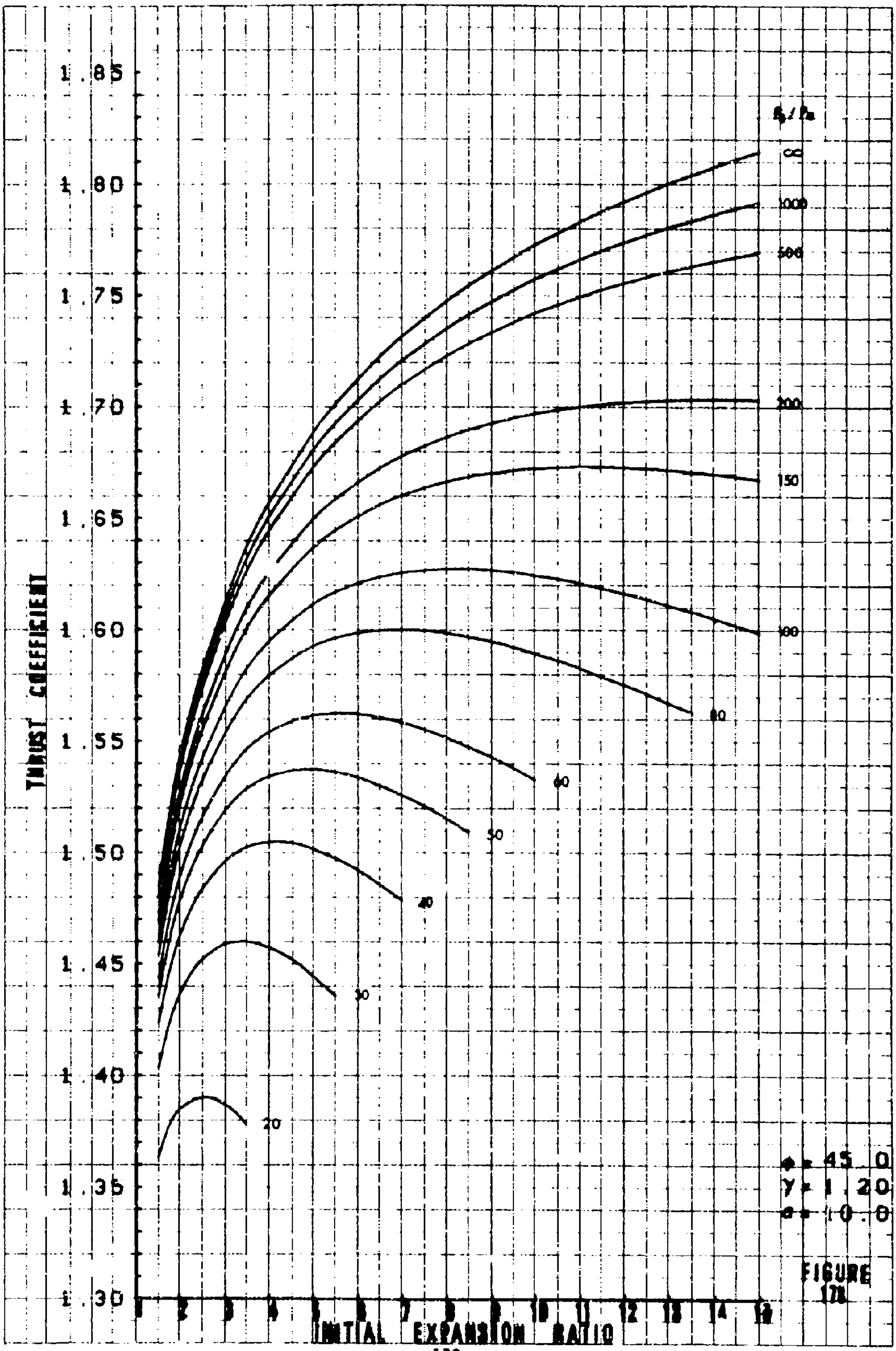

2.00
1.50
1.00
.50
0
-.50
-1.00
-1.50
-2.00
-2.50
-3.00
NON-DIMENSIONAL
∞
1000
500
200
150
100
80
60
50
40
30
20
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
γ = 1.20

FIGURE 177



THRUST COEFFICIENT
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
∞
1000
500
200
150
100
80
60
50
40
30
20
φ= 45.0
γ= 1.20
α= 10.0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
INITIAL EXPANSION RATIO

FIGURE 178

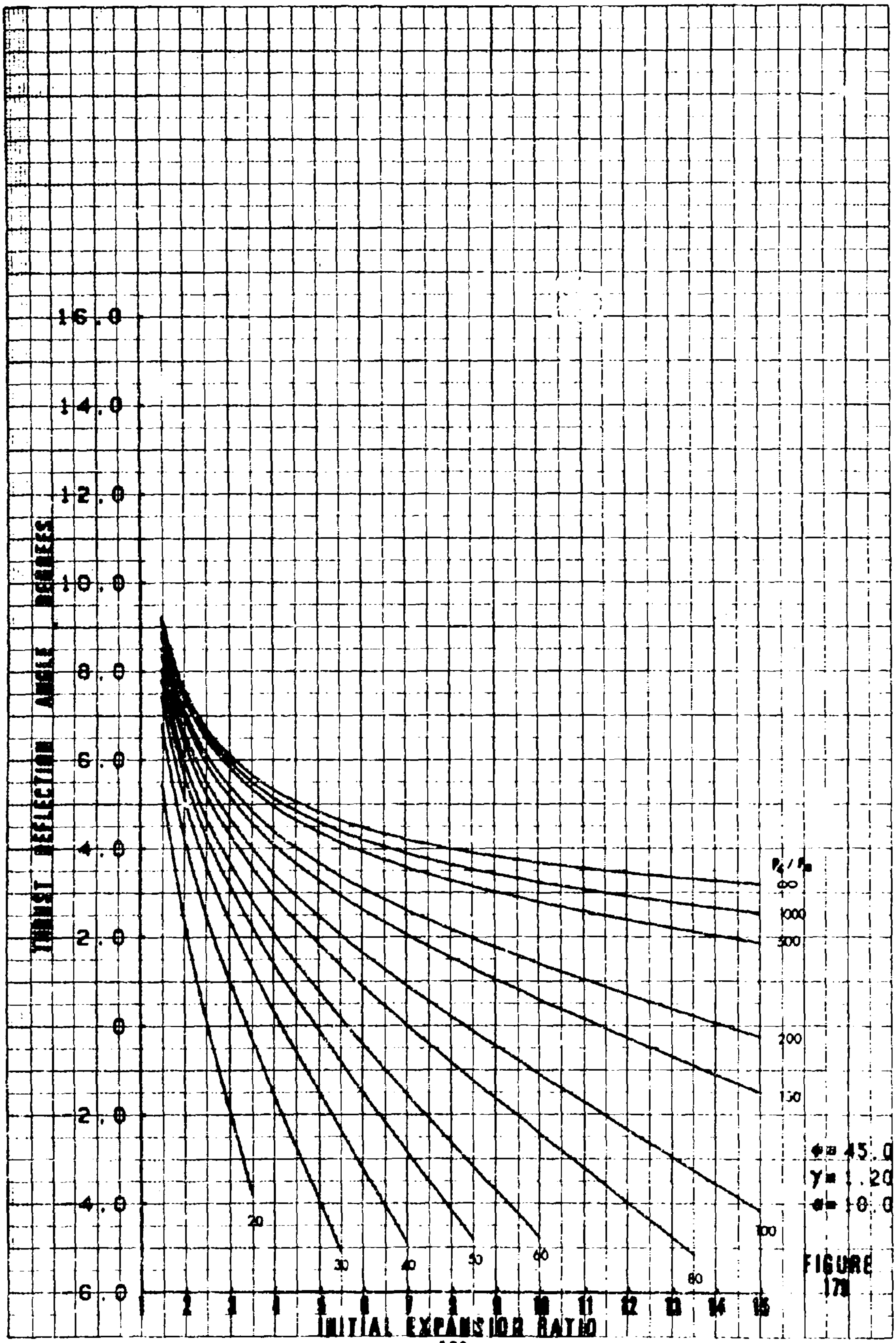
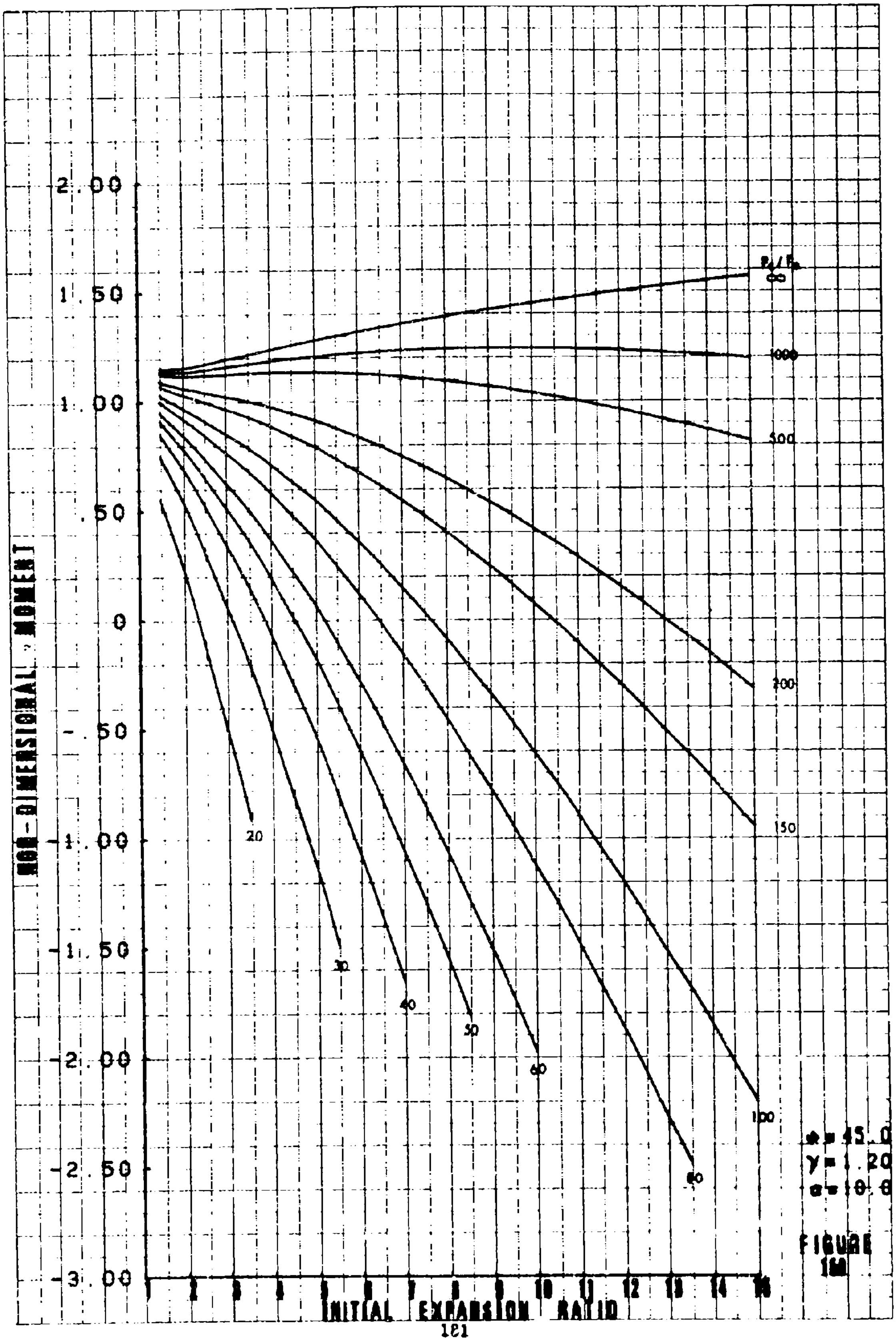
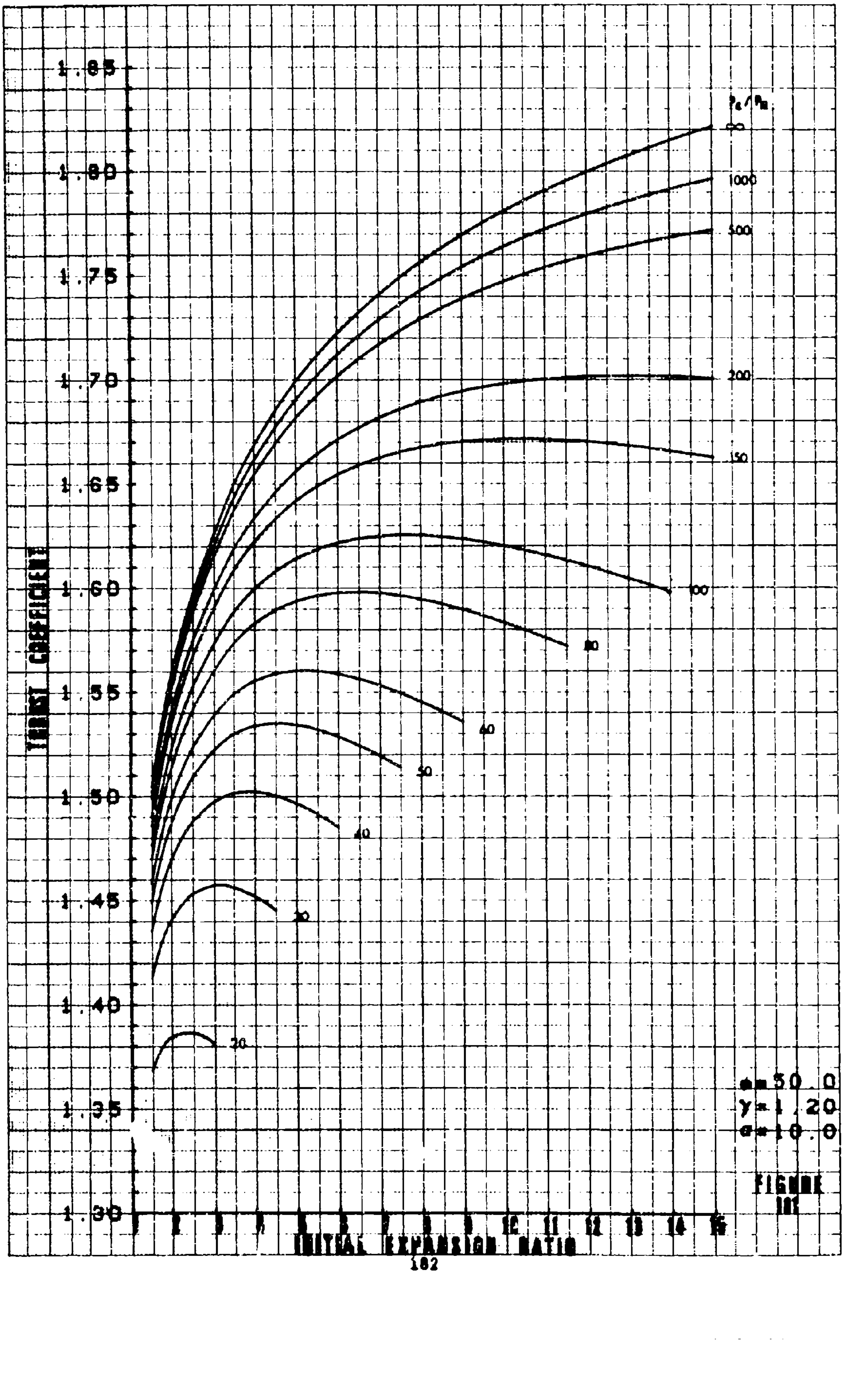

THRUST DEFLECTION ANGLE DEGREES
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0
-2.0
-4.0
-6.0
2
3
4
5
6
7
8
9
10
11
12
13
14
15
INITIAL EXPANSION RATIO
∞
1000
500
200
150
100
80
60
50
40
30
20
ϕ = 45.0
γ = 1.20
α = 0.0

FIGURE 178

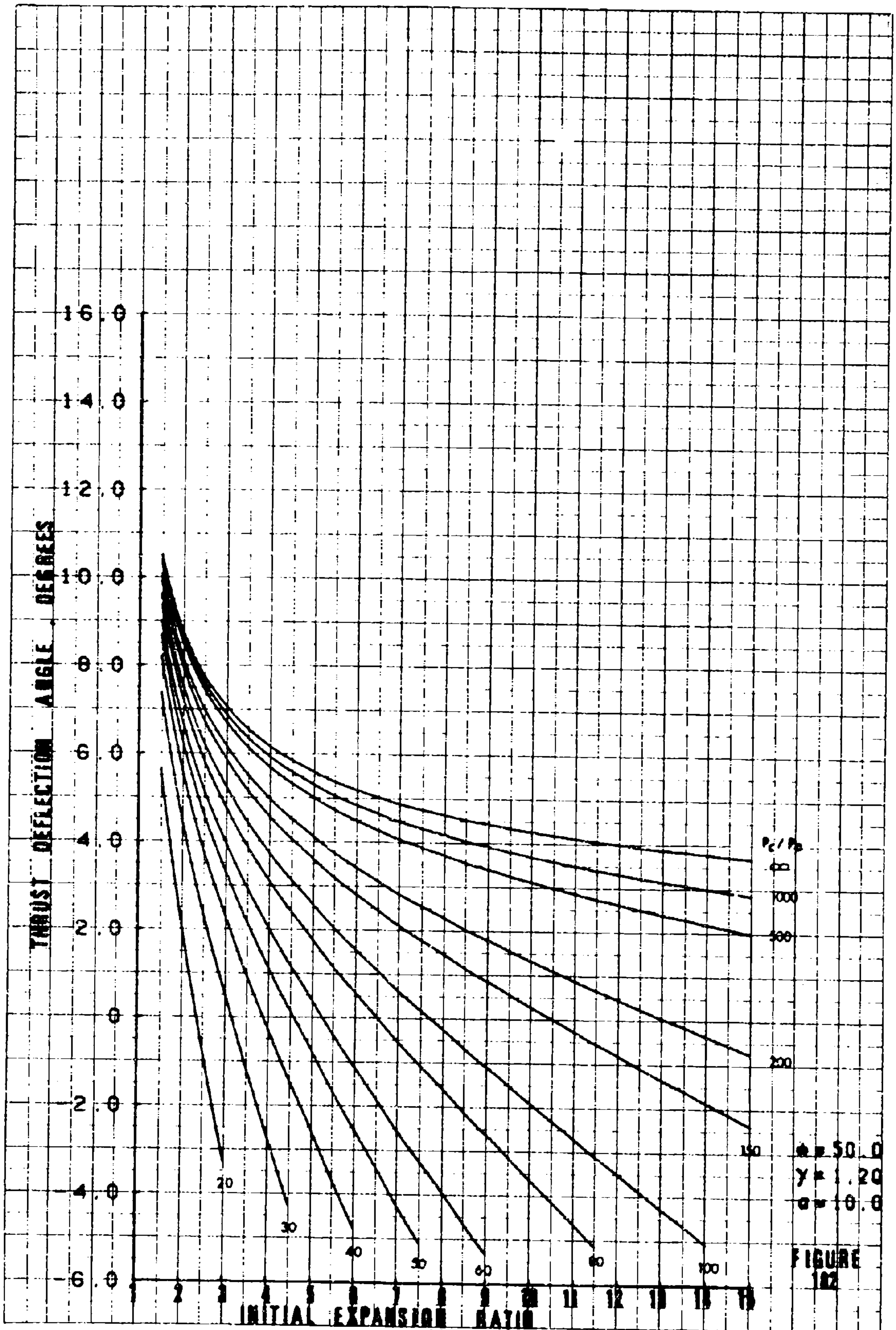


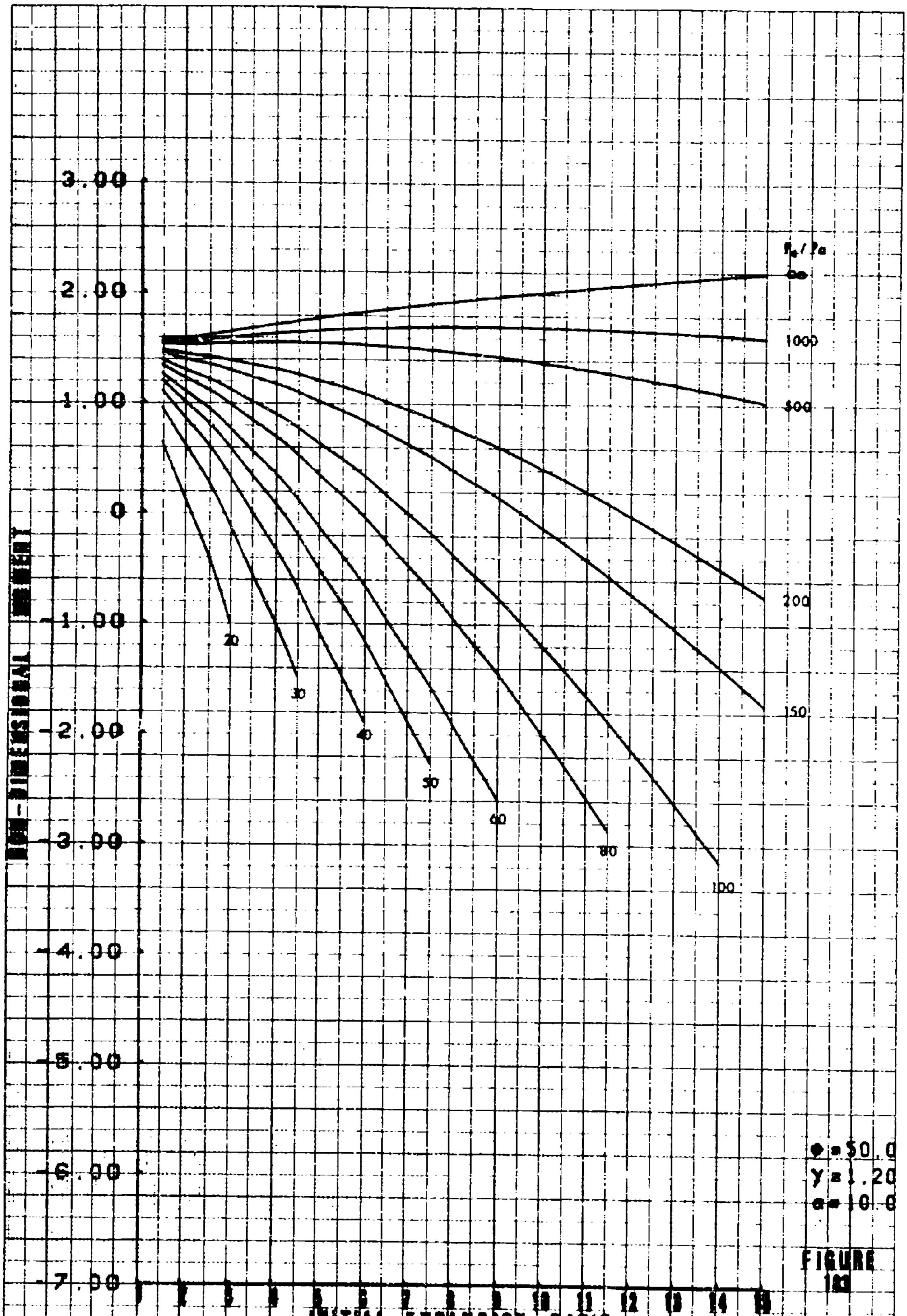
θ = 45.0
γ = 1.20
α = 0.0

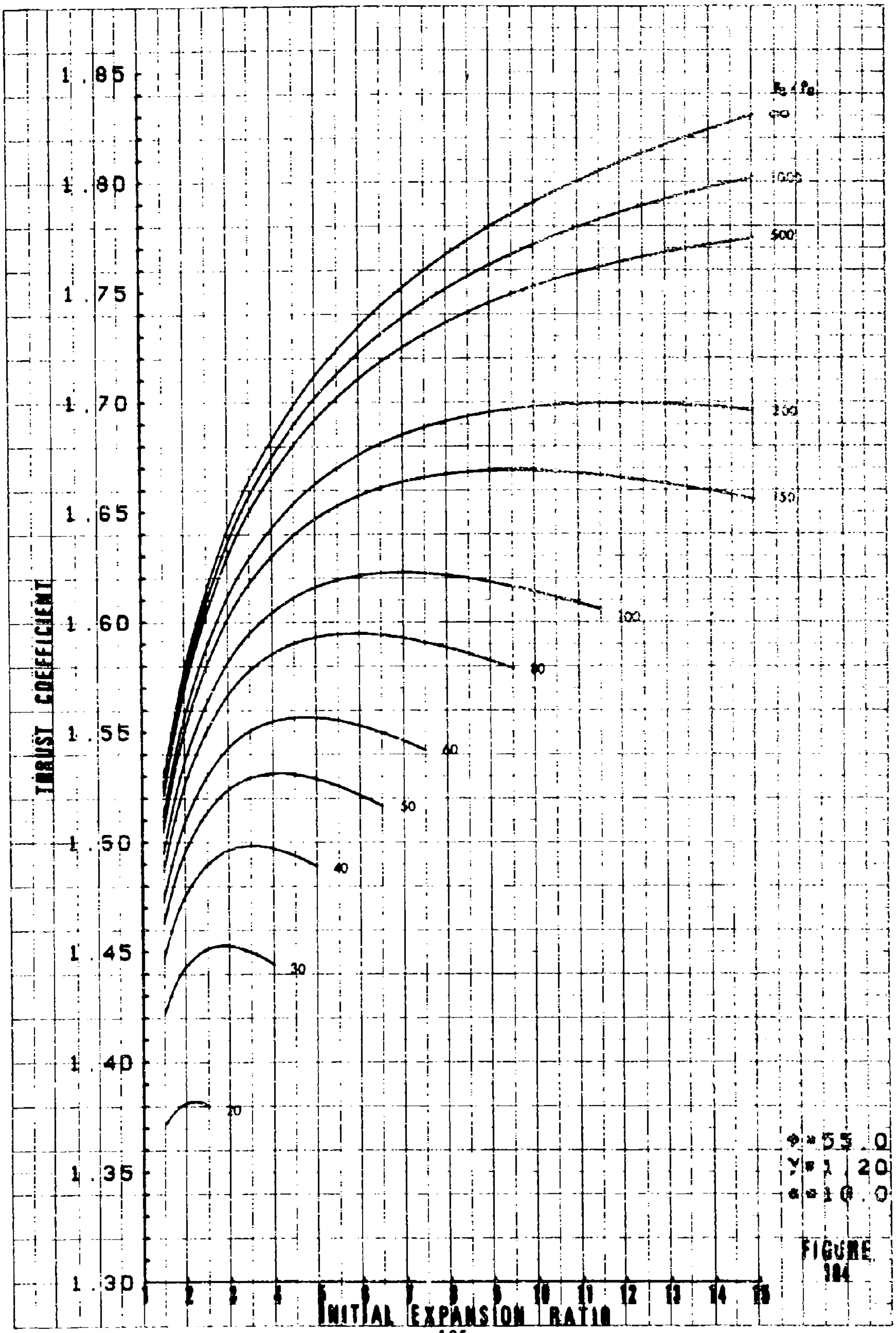
FIGURE 1M

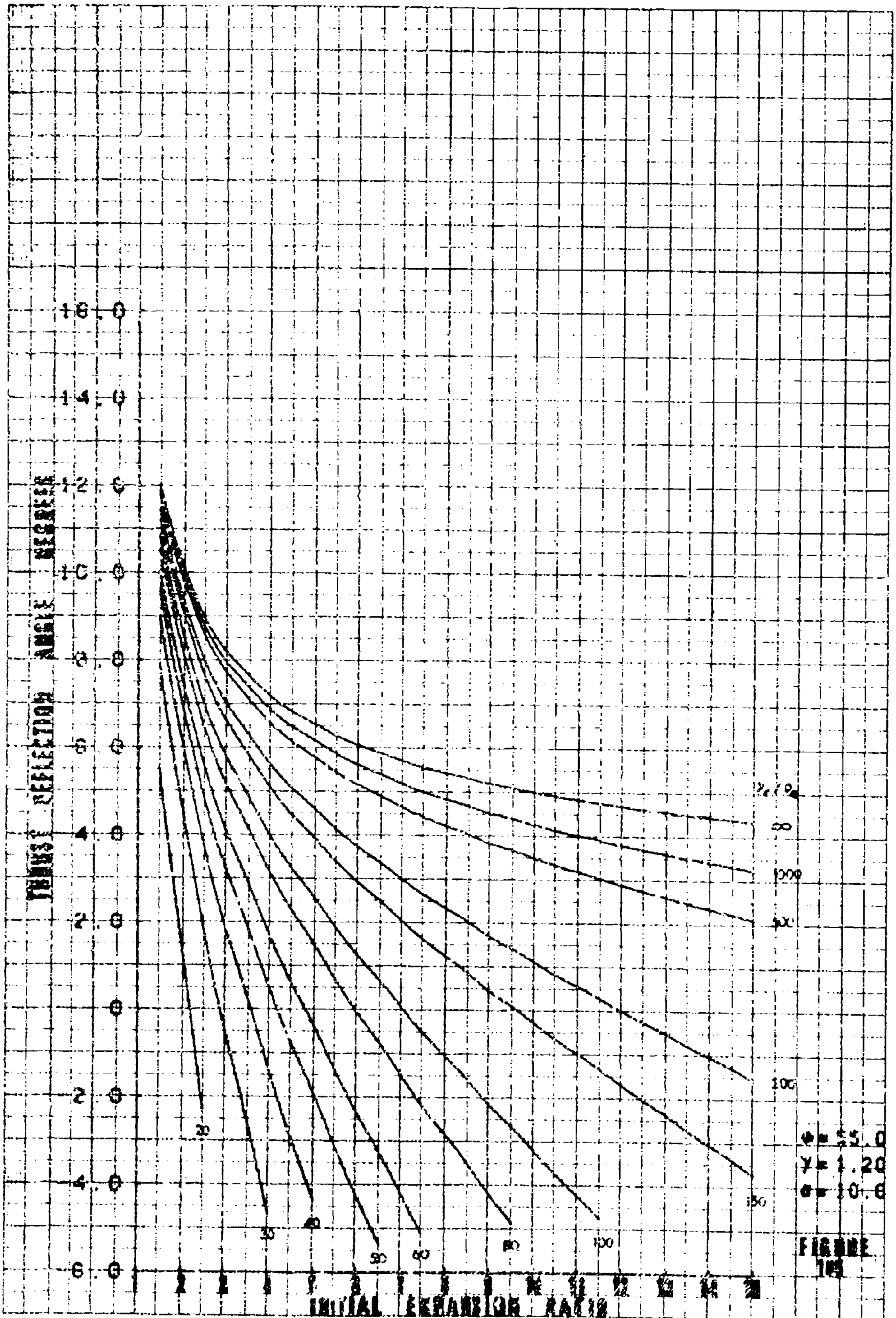


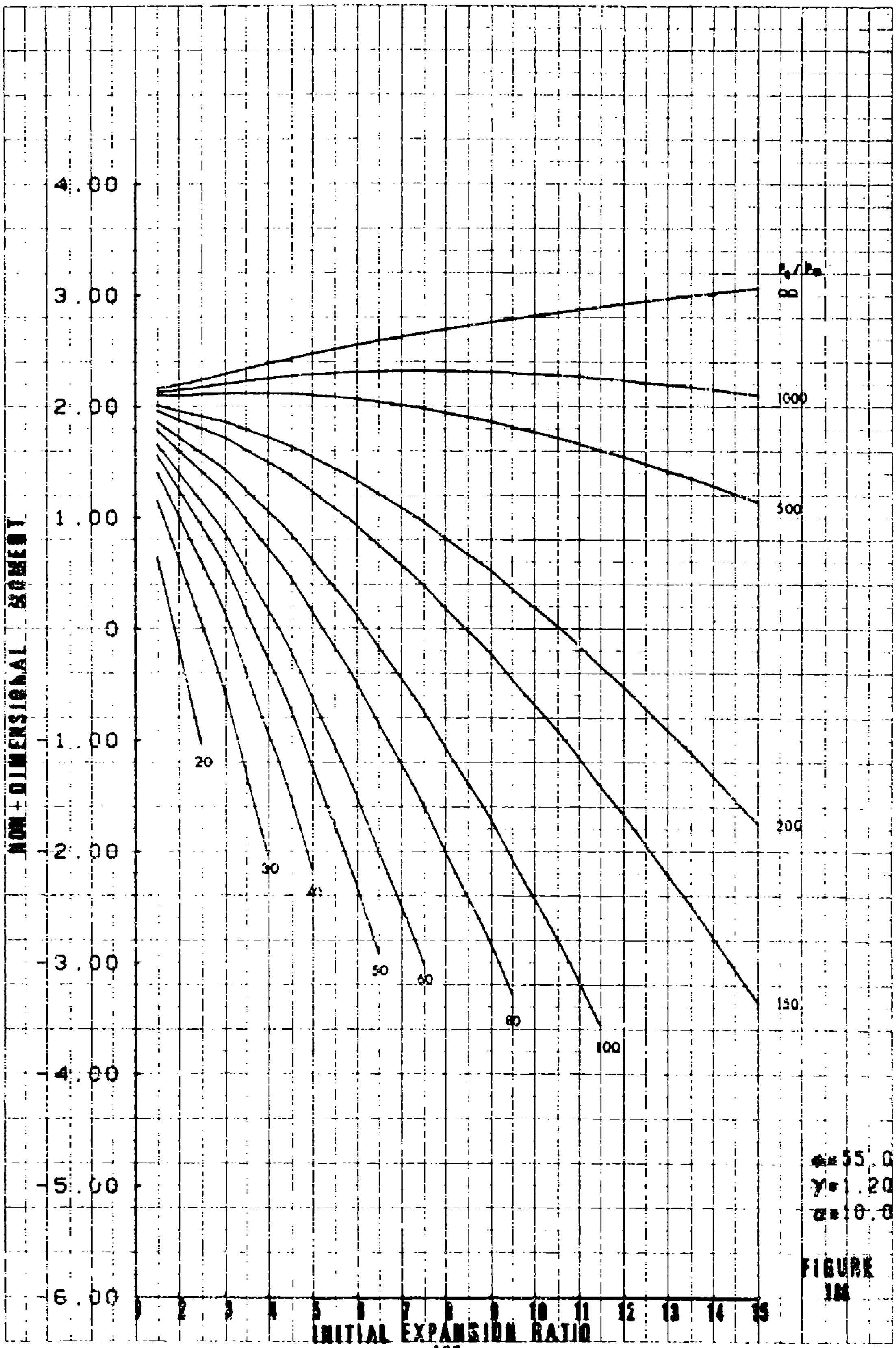
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
THRUST COEFFICIENT
INITIAL EXPANSION RATIO
P_c/P_a
∞
1000
500
200
150
100
80
60
50
40
30
20
FIGURE


THRUST DEFLECTION ANGLE, DEGREES
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0
-2.0
-4.0
-6.0
INITIAL EXPANSION RATIO
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
P_c/P_a
∞
1000
500
200
150
100
80
60
50
40
30
20
φ = 50.0
γ = 1.20
α = 0.0
FIGURE 182


3.00
2.00
1.00
0
-1.00
-2.00
-3.00
-4.00
-5.00
-6.00
-7.00
1000
500
200
150
100
80
60
50
40
30
20
INITIAL EXPANSION RATIO
FIGURE

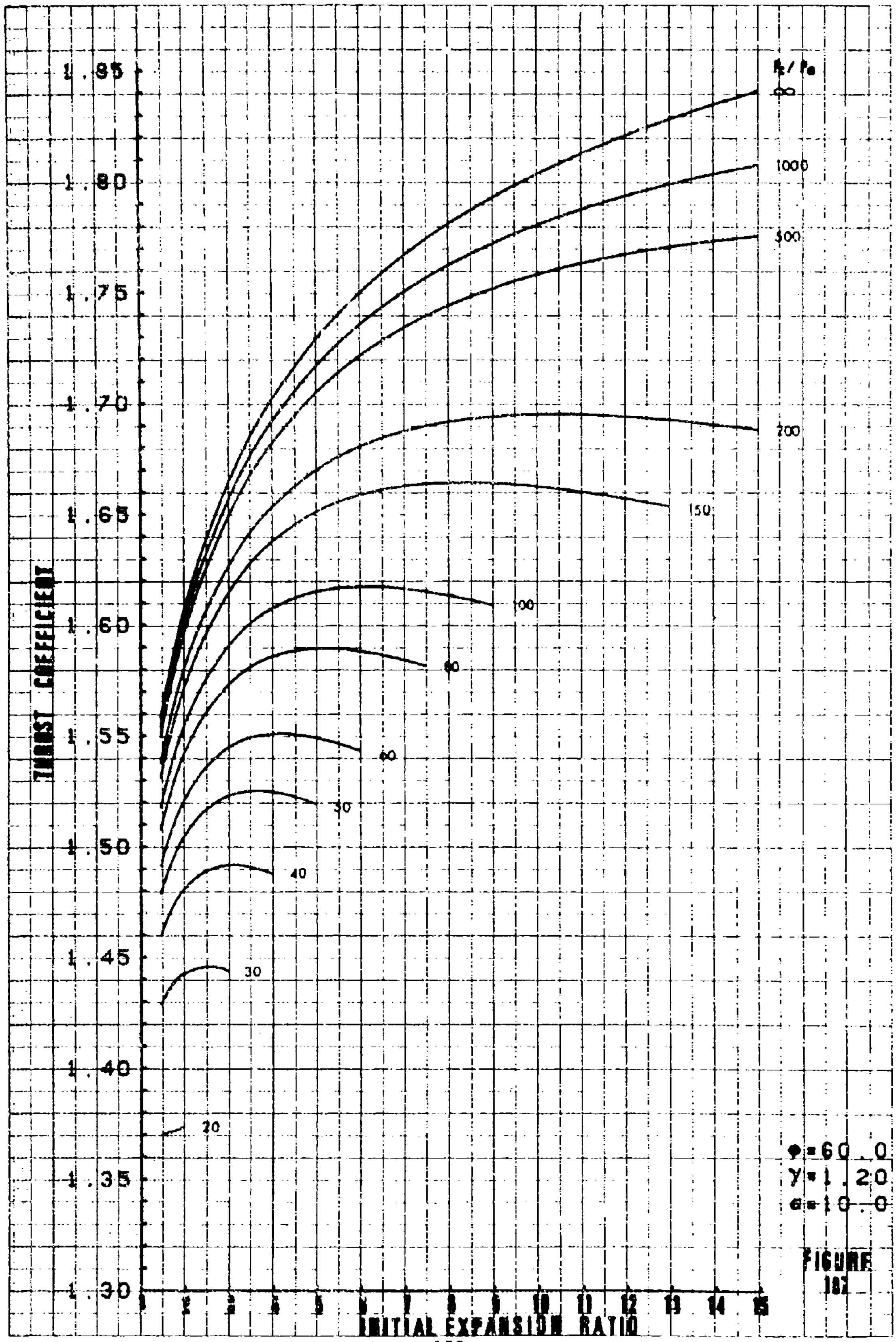

THRUST COEFFICIENT
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
INITIAL EXPANSION RATIO
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
∞
1000
500
200
150
100
80
60
50
40
30
20
Φ = 55.0
γ = 1.20
α = 10.0
FIGURE 184

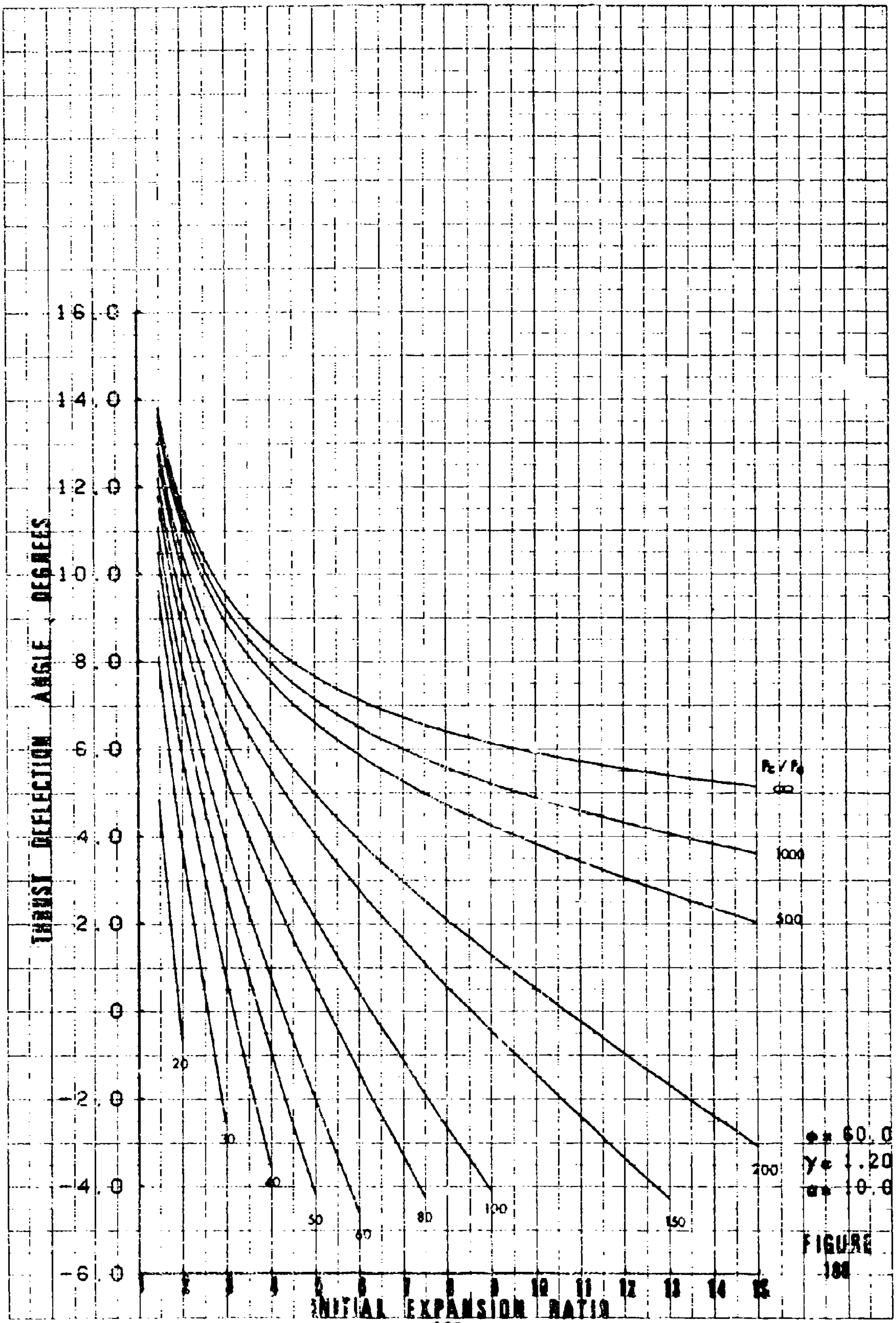

THRUST DEFLECTION ANGLE DEGREES
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0
-2.0
-4.0
-6.0
20
30
40
50
60
80
100
150
100
500
1000
∞
INITIAL EXPANSION RATIO

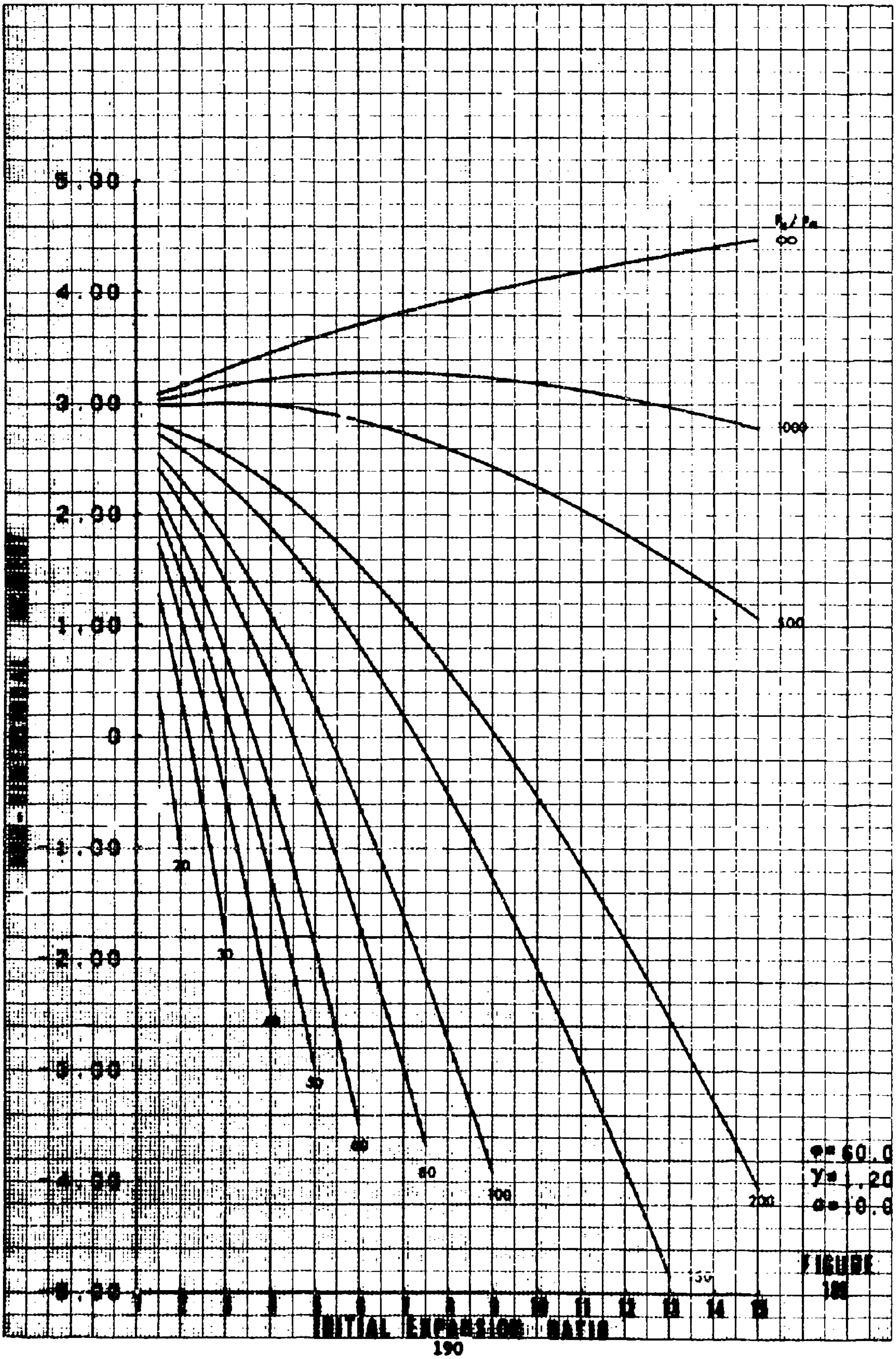


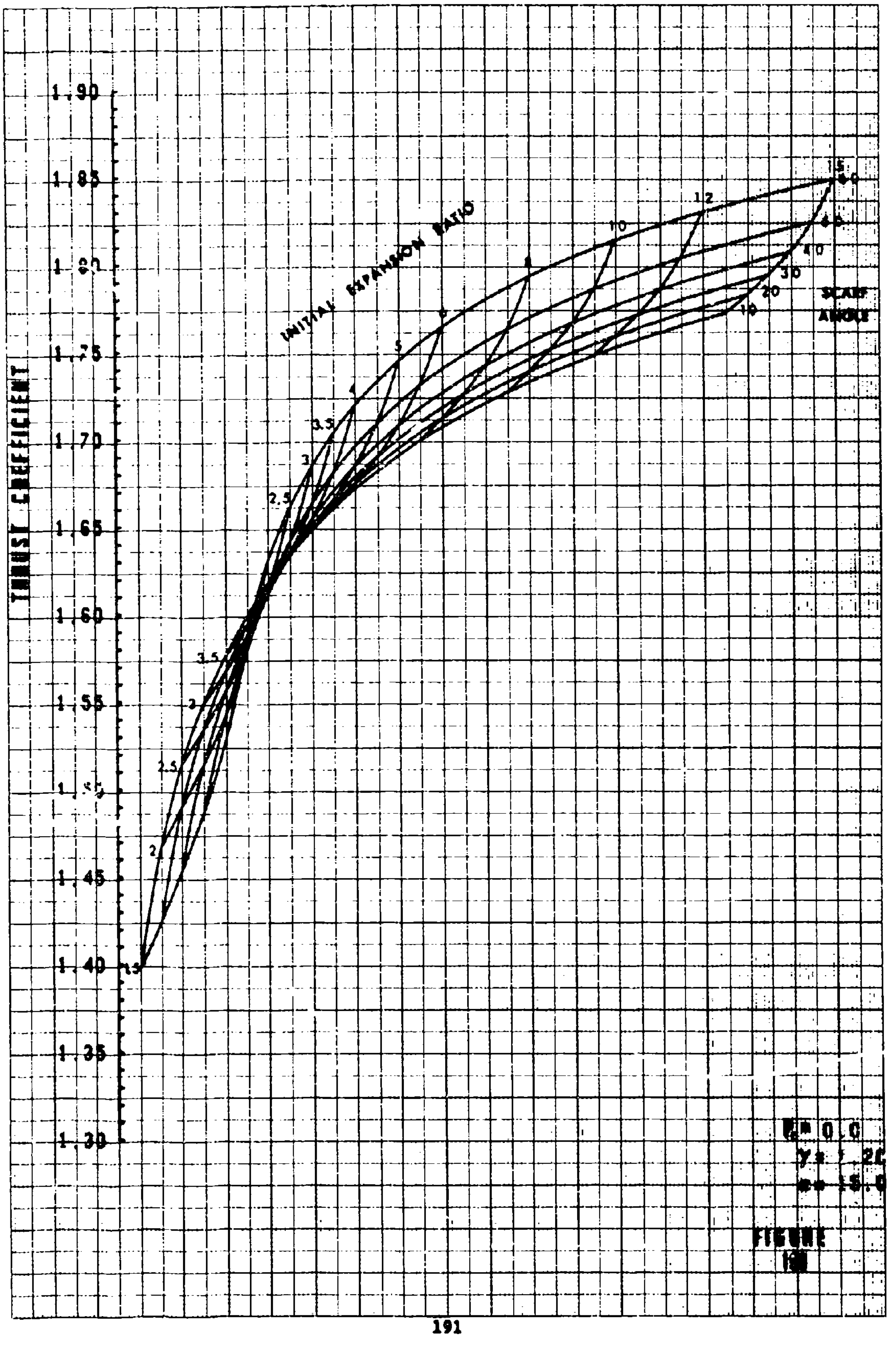
NON-DIMENSIONAL MOMENT
INITIAL EXPANSION RATIO
4.00
3.00
2.00
1.00
0
-1.00
-2.00
-3.00
-4.00
-5.00
-6.00
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
∞
1000
500
200
150
100
80
60
50
40
30
20
φ=55.0
γ=1.20
α=10.0

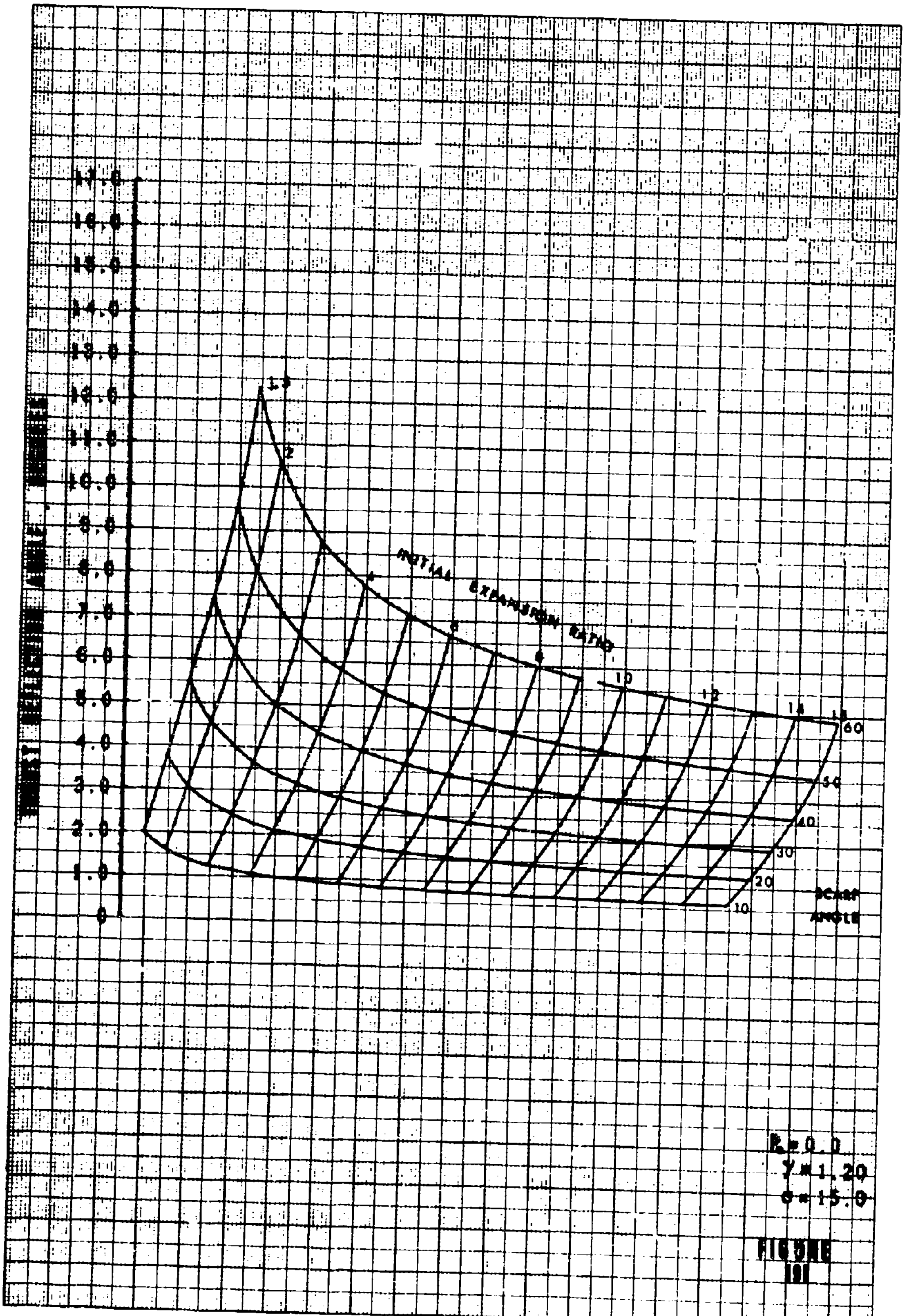
FIGURE 1A


1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
THRUST COEFFICIENT
INITIAL EXPANSION RATIO
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
P_c/P_a
∞
1000
500
200
150
100
80
60
50
40
30
20
φ=60.0
γ=1.20
ε=10.0
FIGURE
182


THRUST DEFLECTION ANGLE, DEGREES
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0
-2.0
-4.0
-6.0
INITIAL EXPANSION RATIO
P_c/P_e
1000
500
200
150
100
80
60
50
40
30
20
ϕ = 60.0
γ = 1.20
α = 0.0
FIGURE


5.00
4.00
3.00
2.00
1.00
0
-1.00
-2.00
P_c/P_a
∞
1000
500
200
150
100
80
60
50
40
30
20
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
INITIAL EXPANSION RATIO


THRUST COEFFICIENT
1.90
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
INITIAL EXPANSION RATIO
SCARF ANGLE
1.5
2
2.5
3
3.5
4
5
6
8
10
12
15
10
20
30
40
FIGURE



17.0
16.0
15.0
14.0
13.0
12.0
11.0
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
INITIAL EXPANSION RATIO
1.5
2
4
8
10
12
14
16
60
50
40
30
20
10
SCARF ANGLE
$P_a = 0.0$
$\gamma = 1.20$
$\theta = 15.0$

FIGURE 191

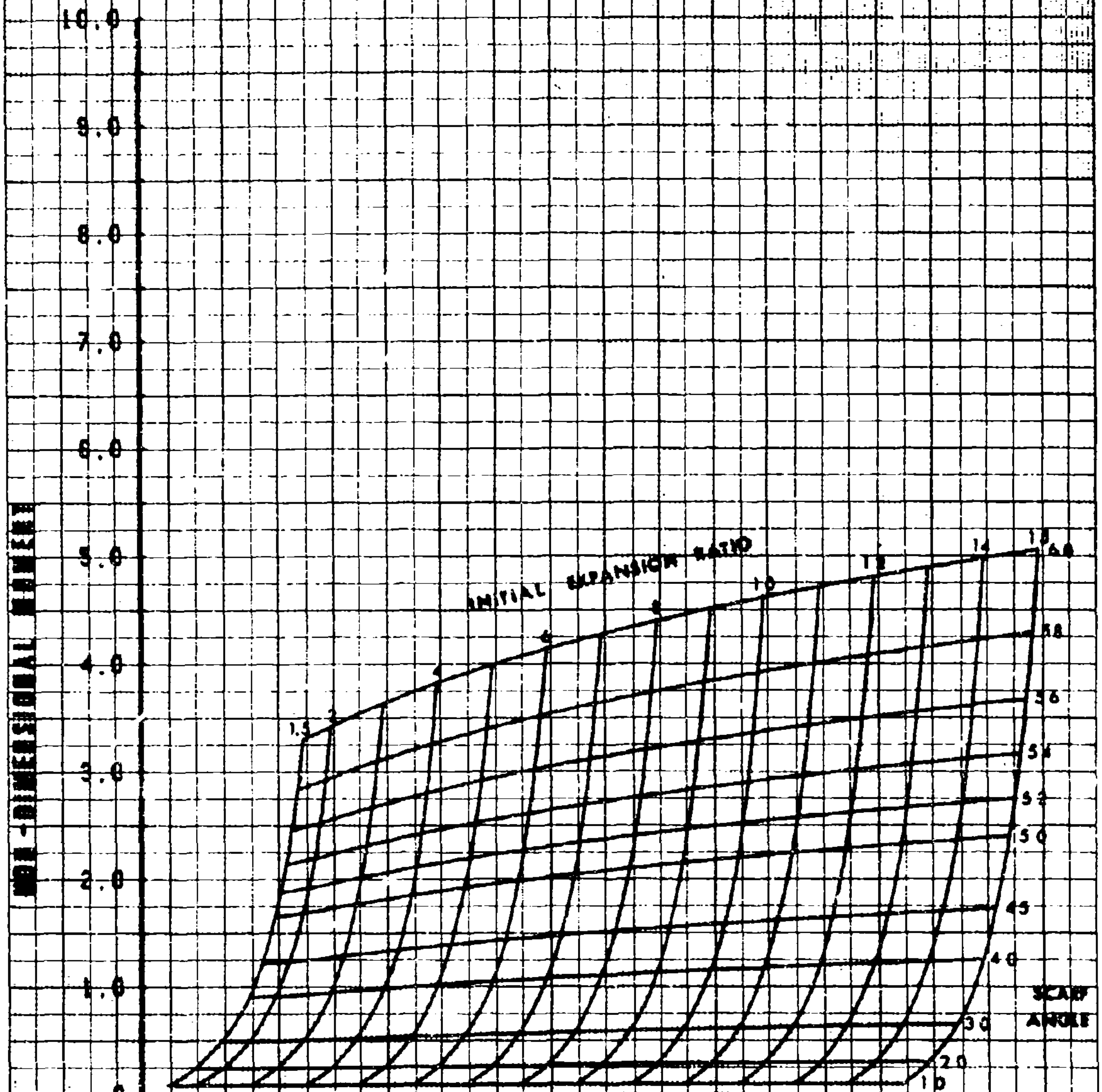
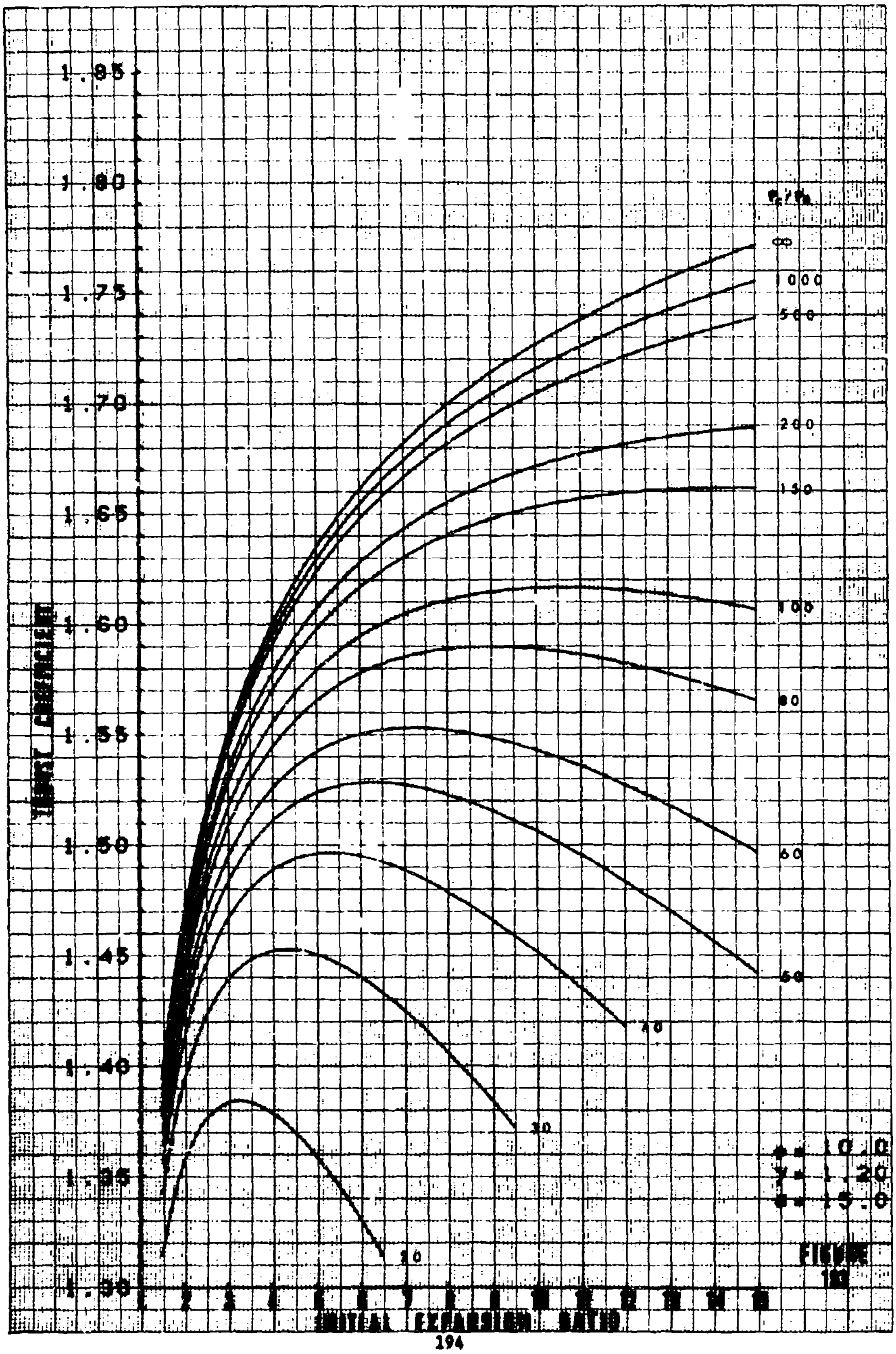

NON-DIMENSIONAL MOMENT
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
INITIAL EXPANSION RATIO
1.5
2
4
6
8
10
12
14
16
60
58
56
54
52
50
45
40
30
20
10
SCARF
ANGLE

FIGURE
192


1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
∞
1000
500
200
150
100
80
60
50
40
30
20
FIGURE

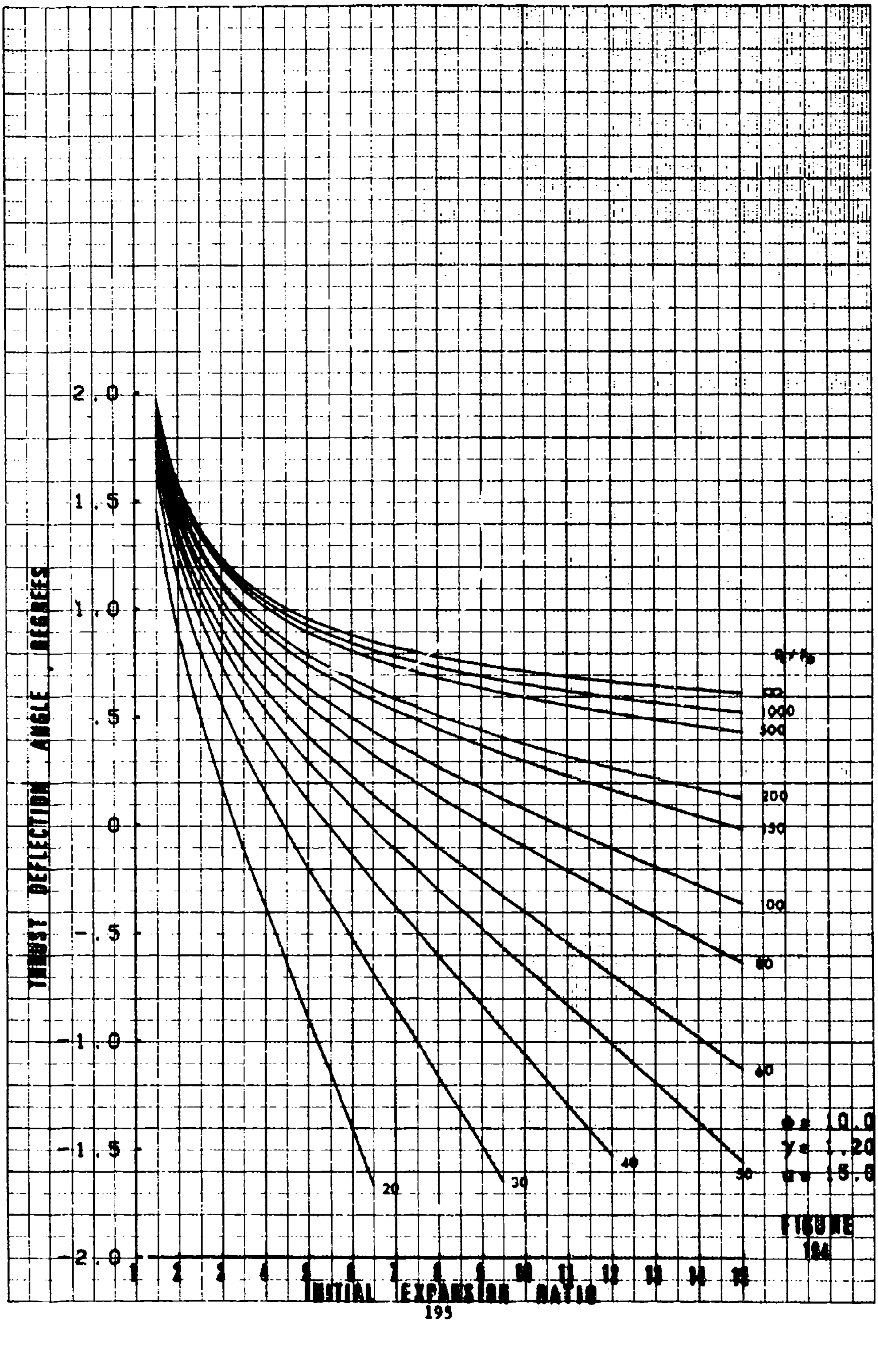
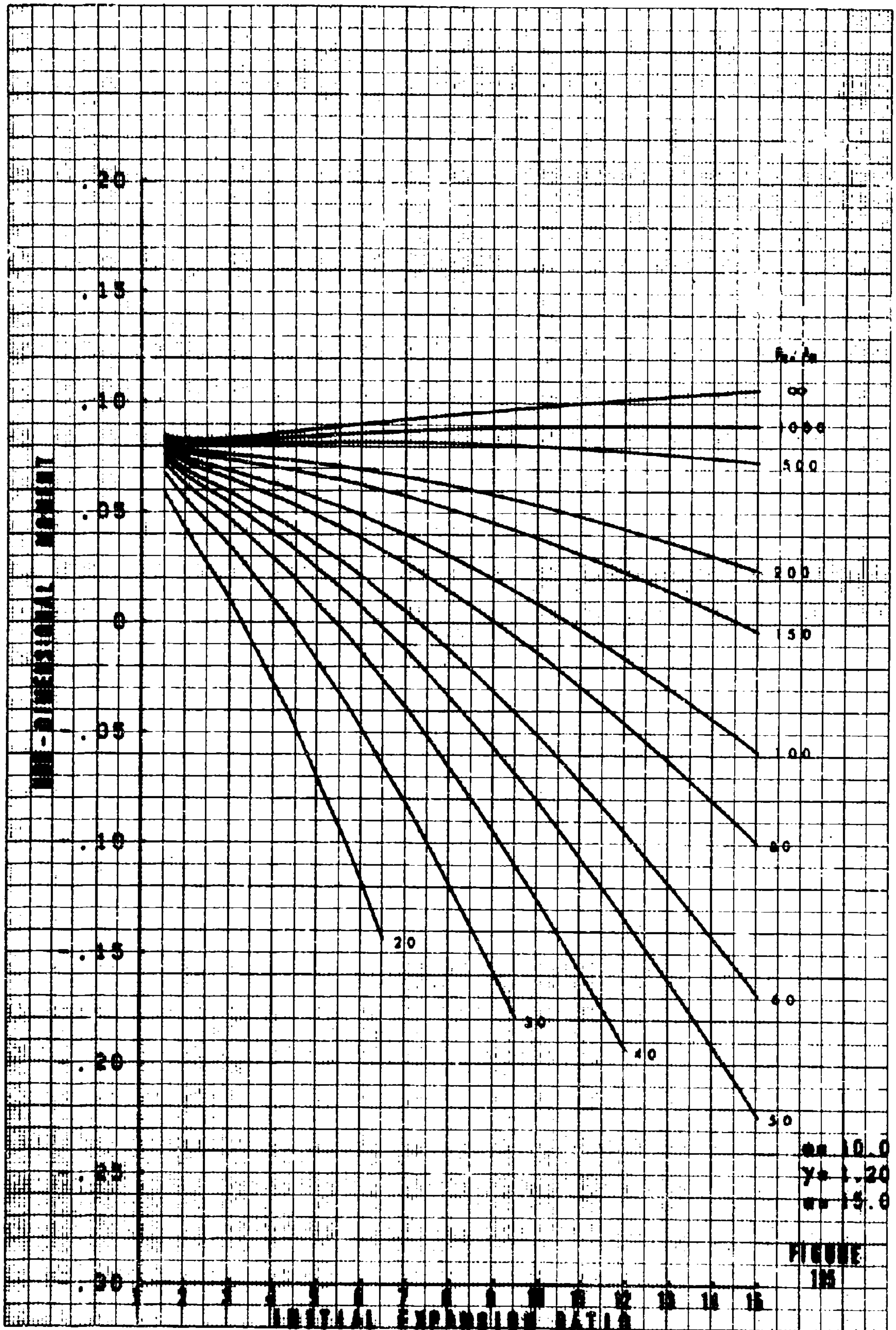
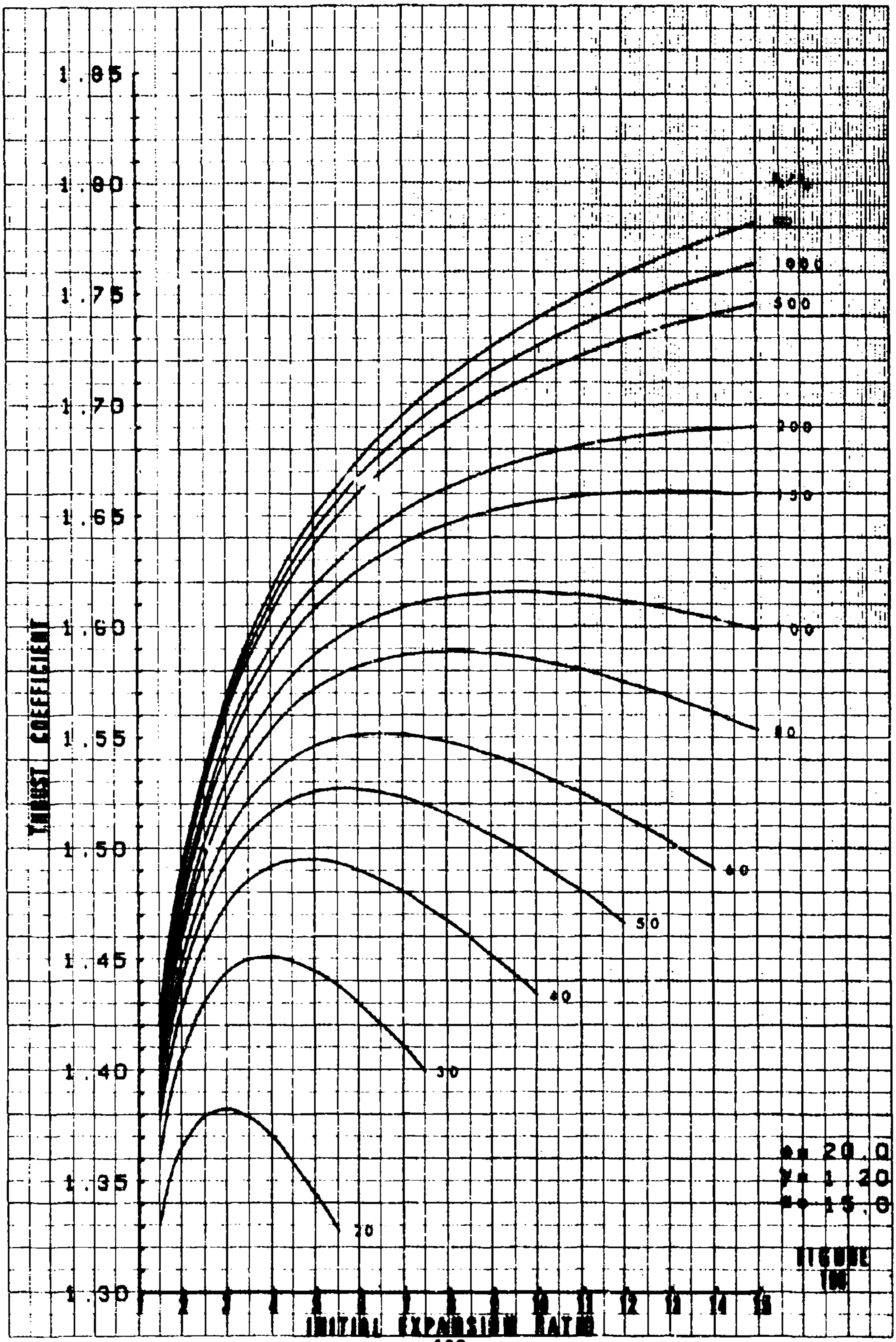
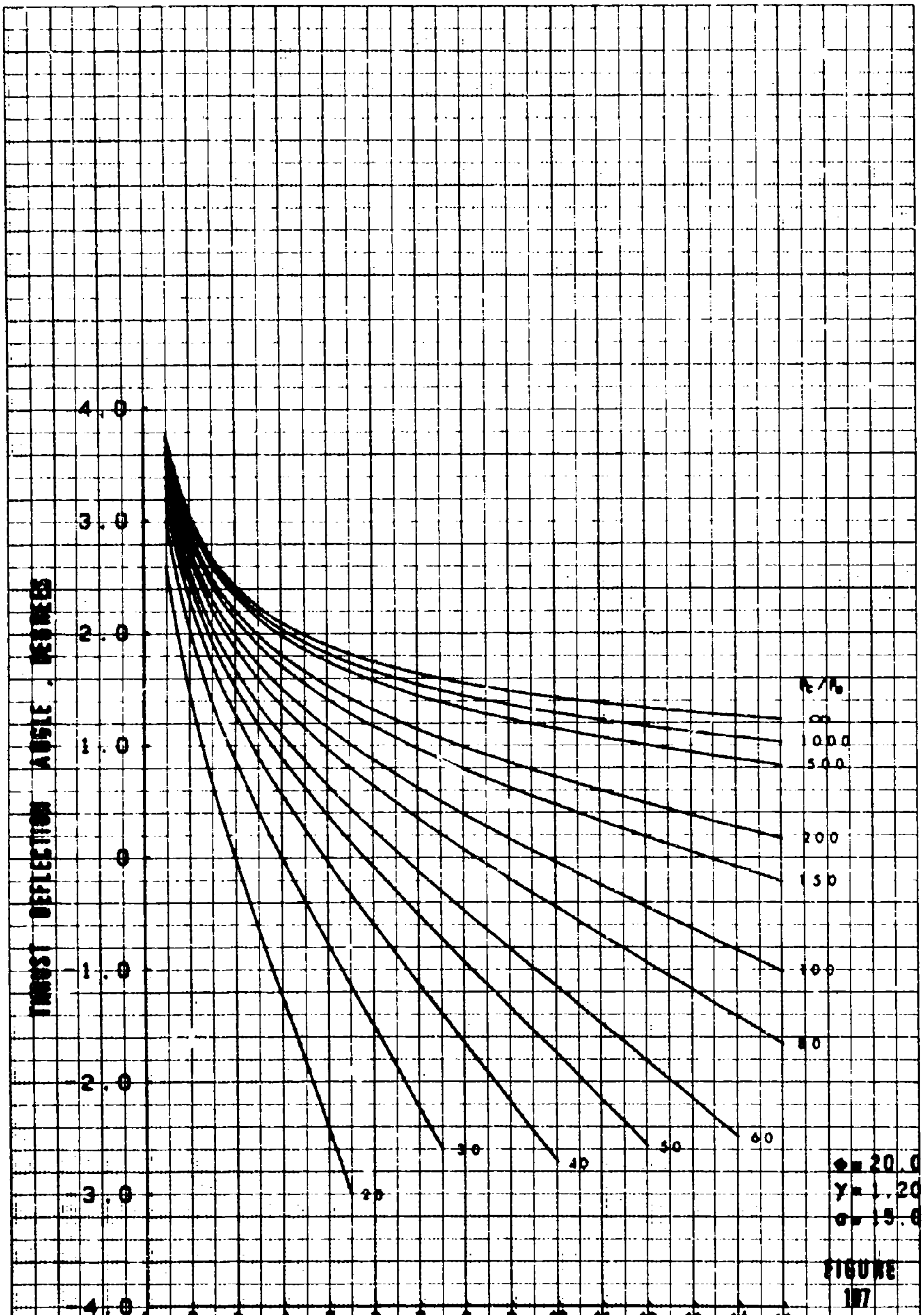

THRUST DEFLECTION ANGLE, DEGREES
2.0
1.5
1.0
.5
0
-.5
-1.0
-1.5
-2.0
INITIAL EXPANSION RATIO
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
1000
500
200
150
100
80
60
50
40
30
20
γ = 1.20

FIGURE 184

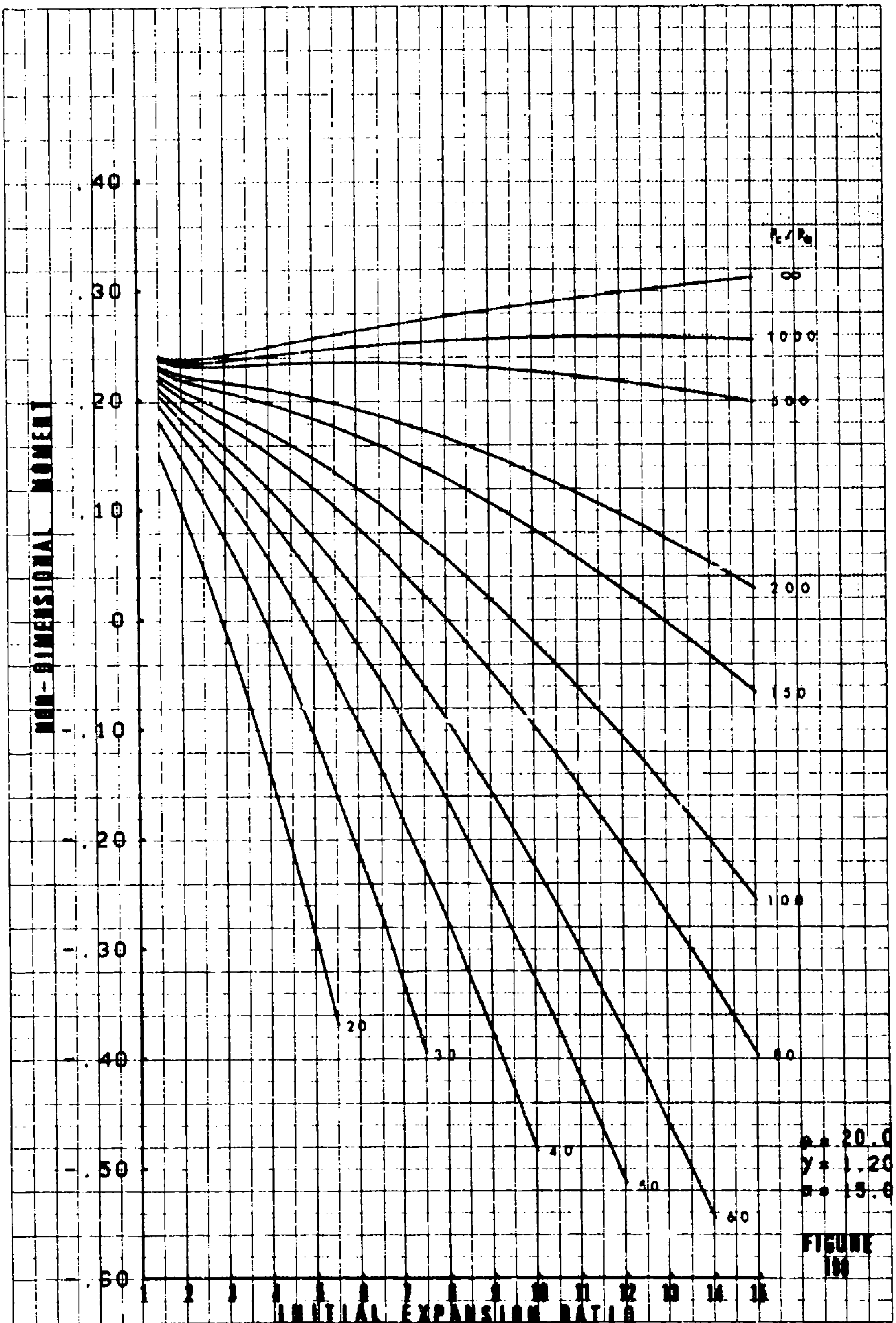

∞
1000
500
200
150
100
80
60
50
40
30
20


1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
THRUST COEFFICIENT
INITIAL EXPANSION RATIO
1000
500
60
50
40
30
20
20.0
1.20
15.0
FIGURE

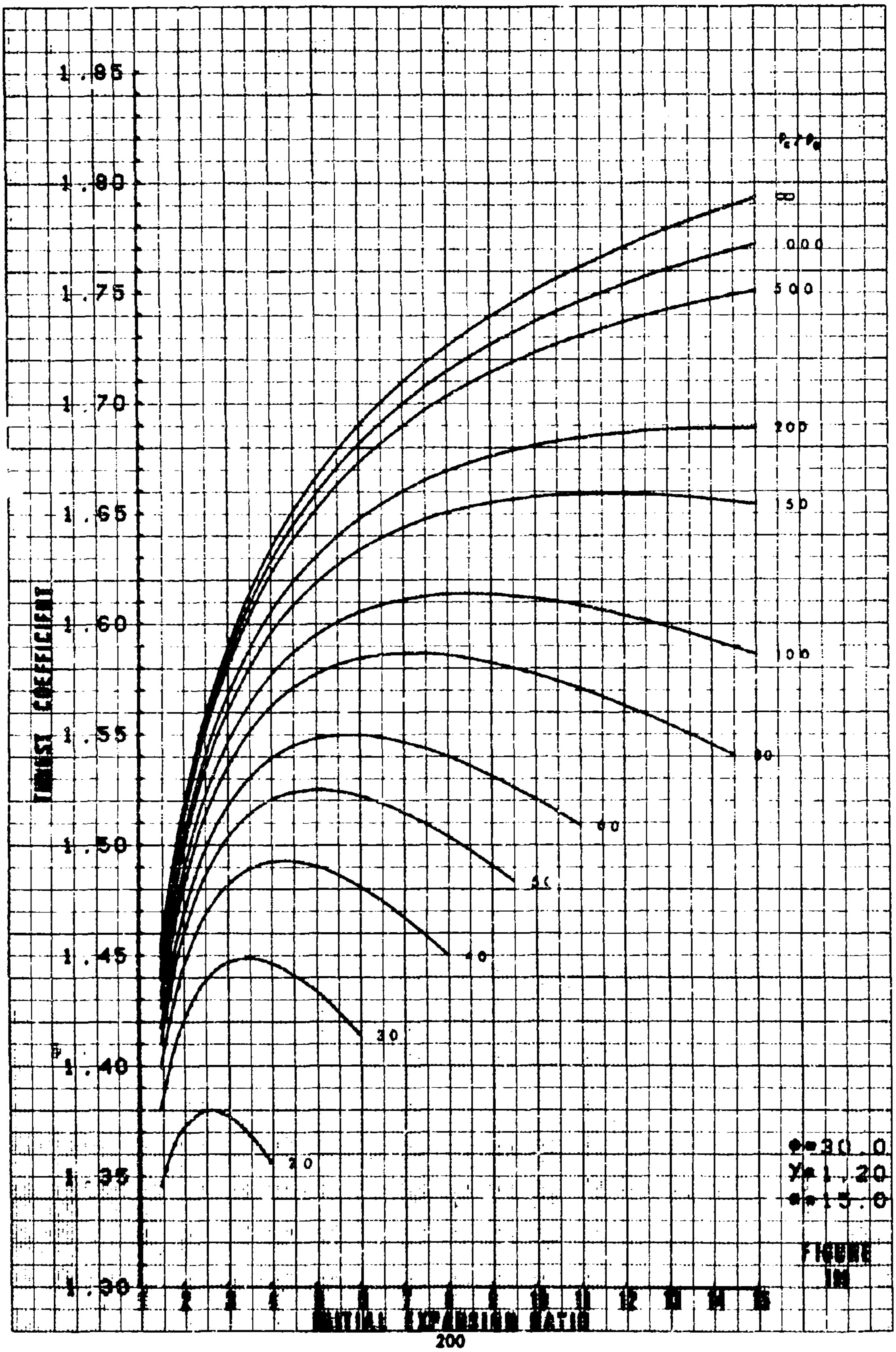


ϕ = 20.0
γ = 1.20
α = 15.0

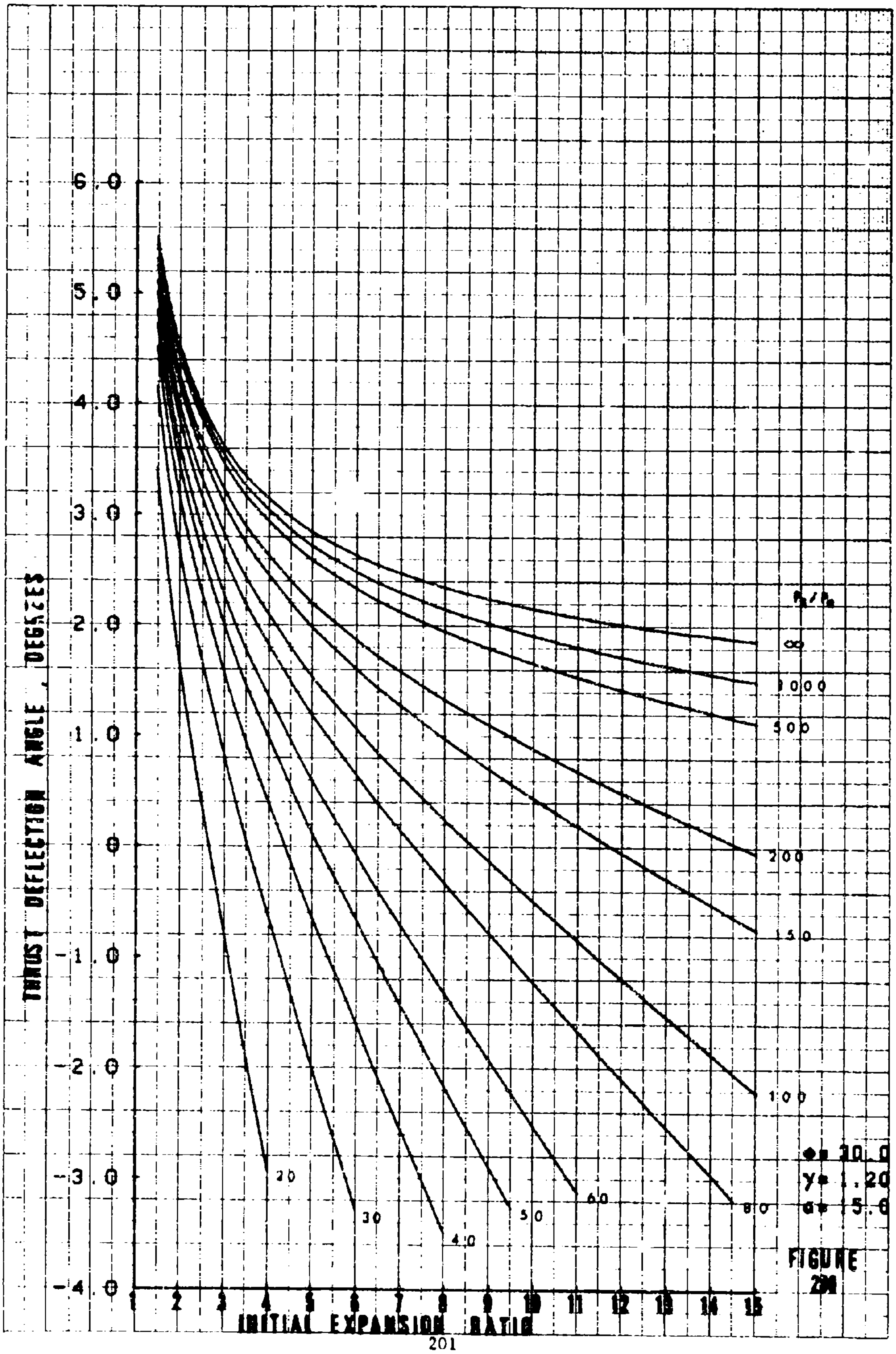
FIGURE
107



NON-DIMENSIONAL MOMENT
INITIAL EXPANSION RATIO
.40
.30
.20
.10
0
-.10
-.20
-.30
-.40
-.50
-.60
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
P_c / P_a
∞
1000
500
200
150
100
80
60
50
40
30
20
γ = 1.20
FIGURE

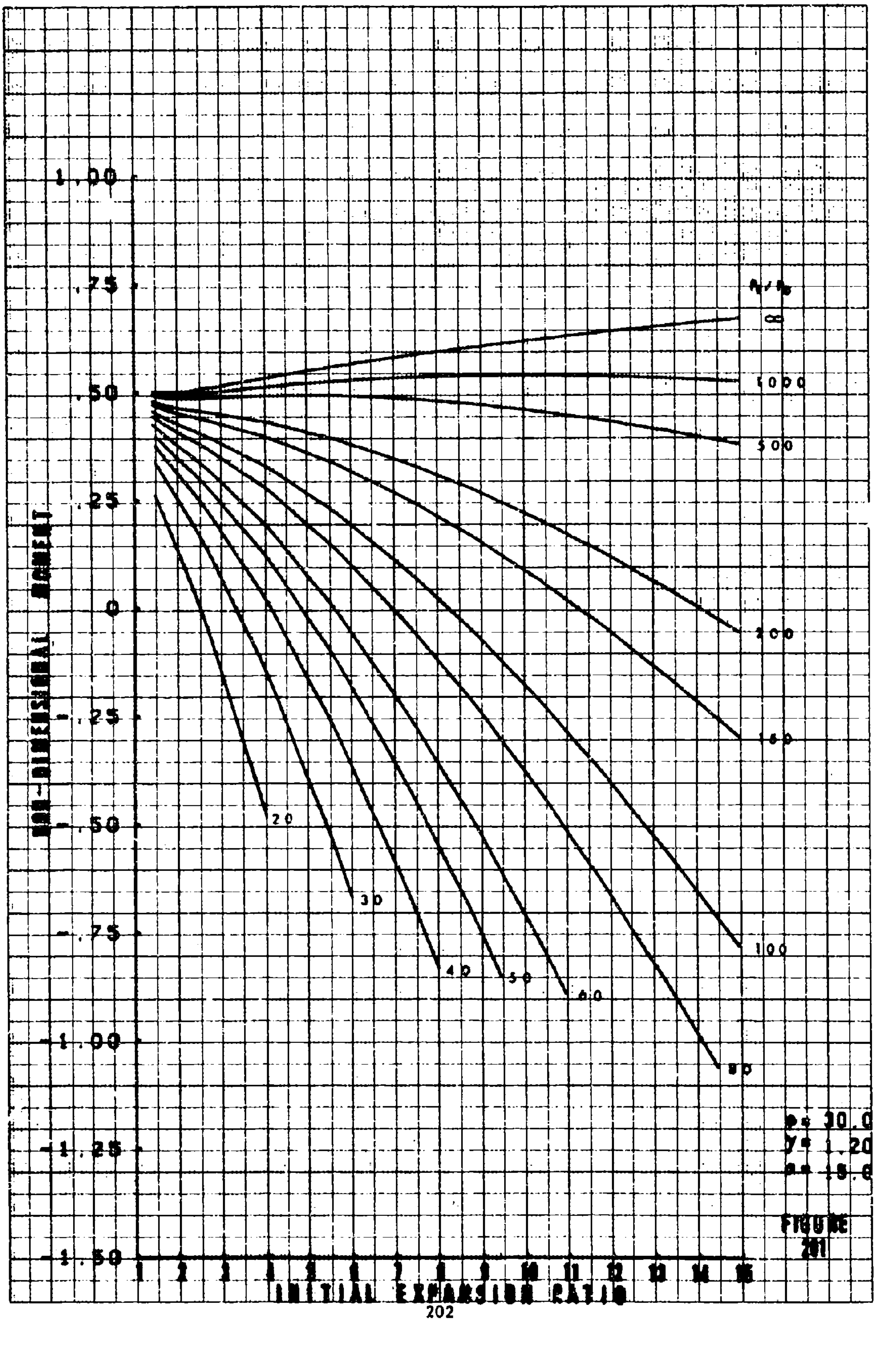


1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
THRUST COEFFICIENT
INITIAL EXPANSION RATIO
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
P_c/P_a
∞
1000
500
200
150
100
80
60
50
40
30
20
φ=30.0
γ=1.20
θ=15.0
FIGURE
1M

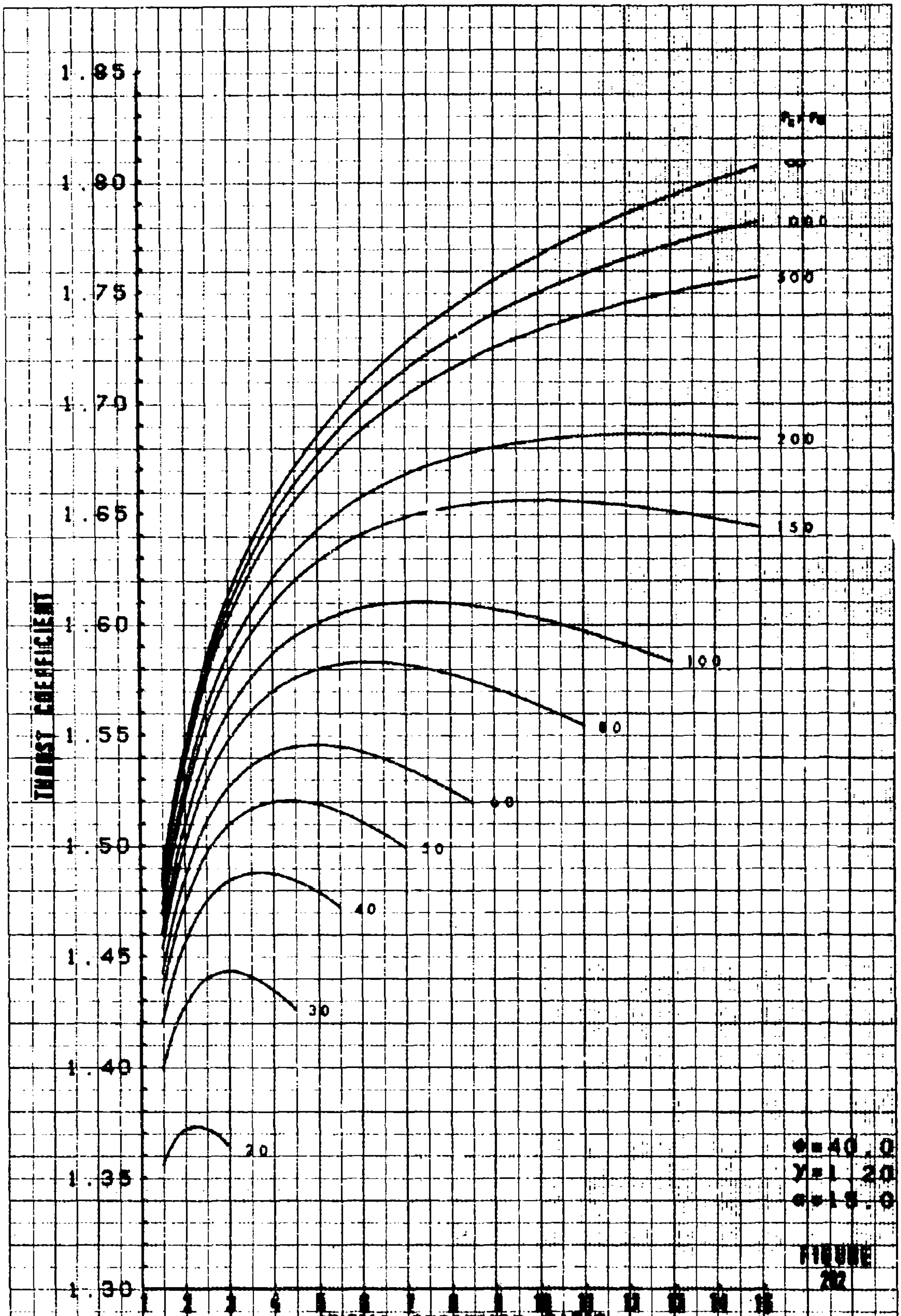


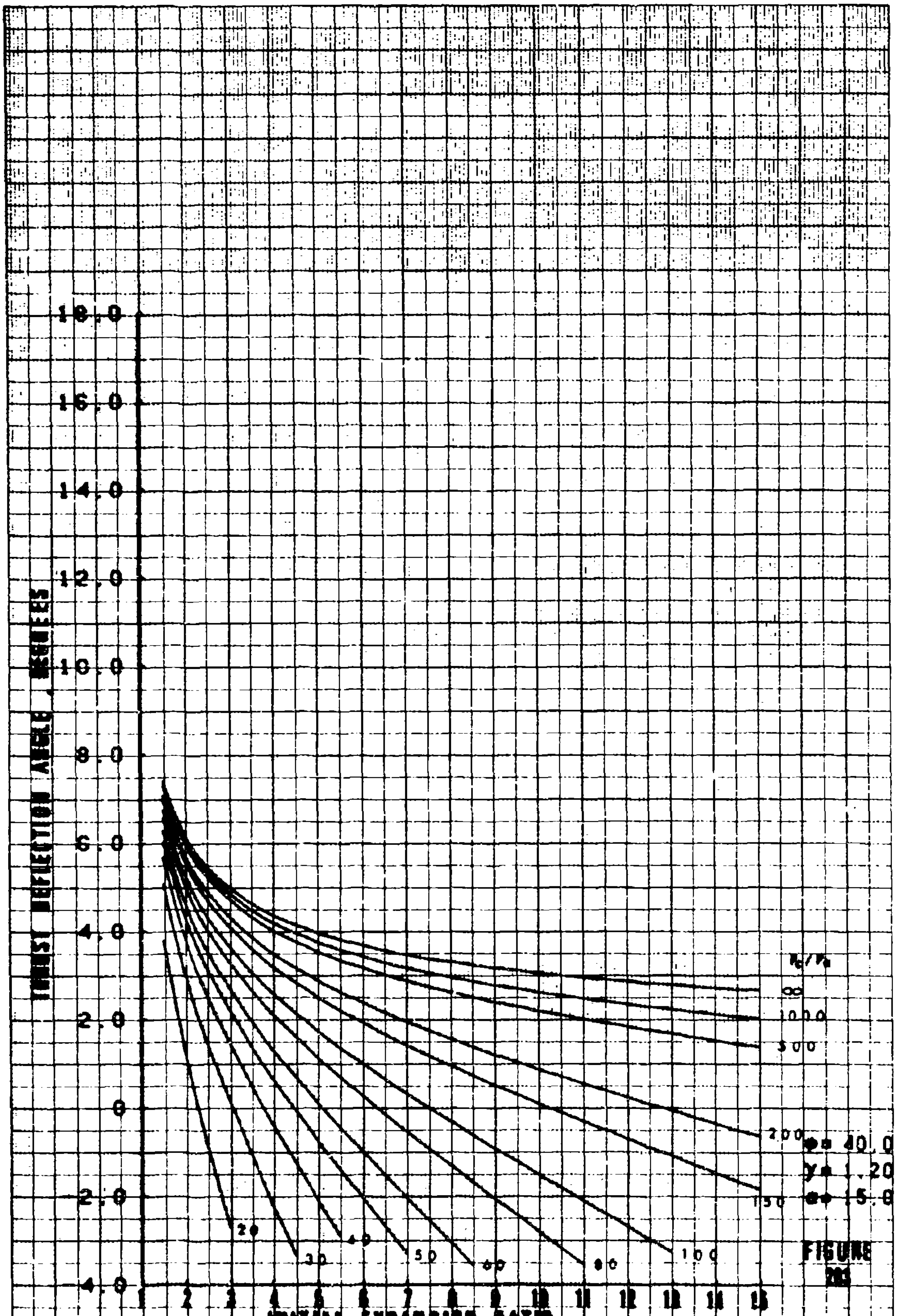
THRUST DEFLECTION ANGLE, DEGREES
INITIAL EXPANSION RATIO
6.0
5.0
4.0
3.0
2.0
1.0
0
-1.0
-2.0
-3.0
-4.0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
∞
1000
500
200
150
100
80
60
50
40
30
20
γ= 1.20

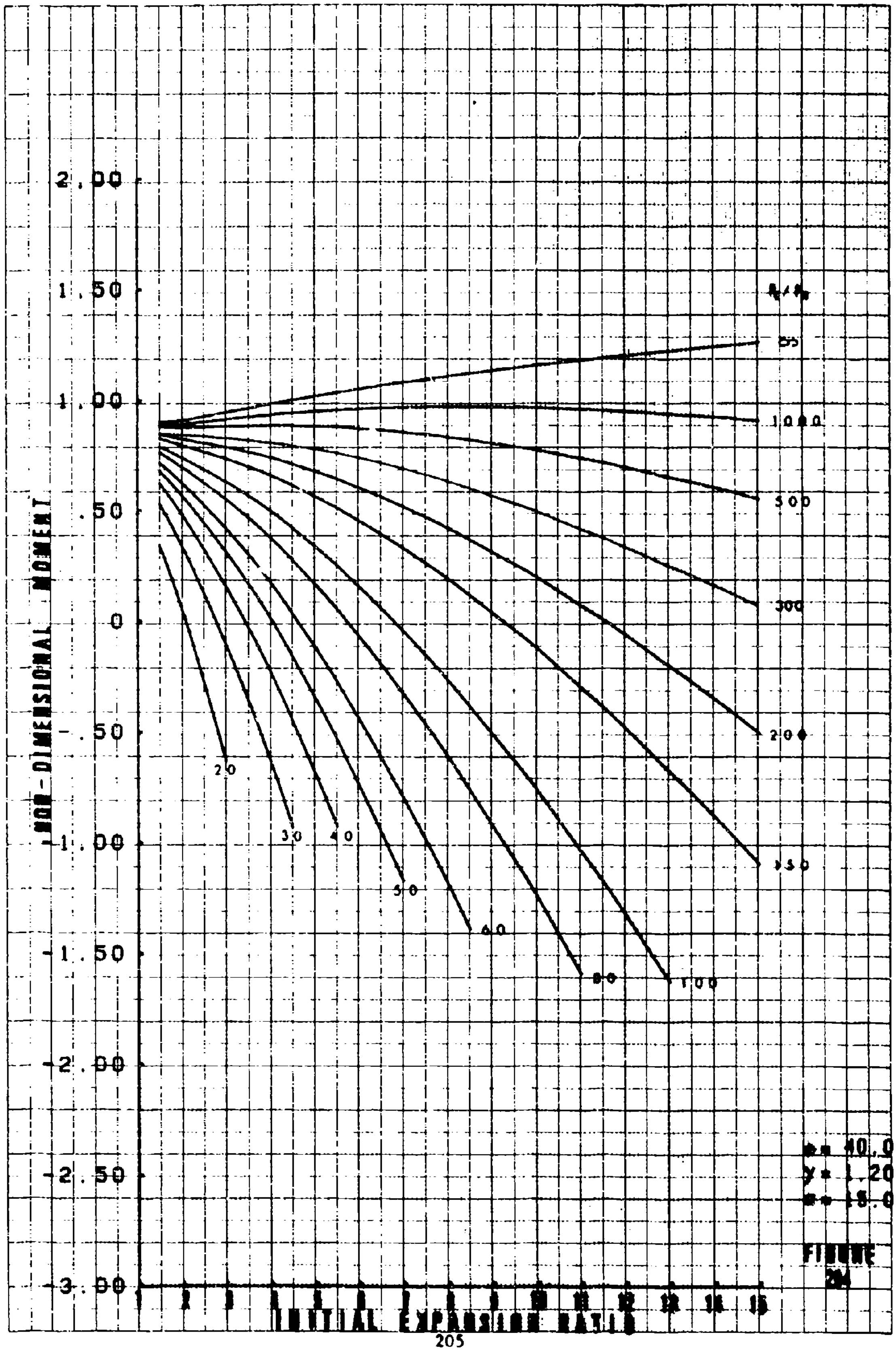
FIGURE



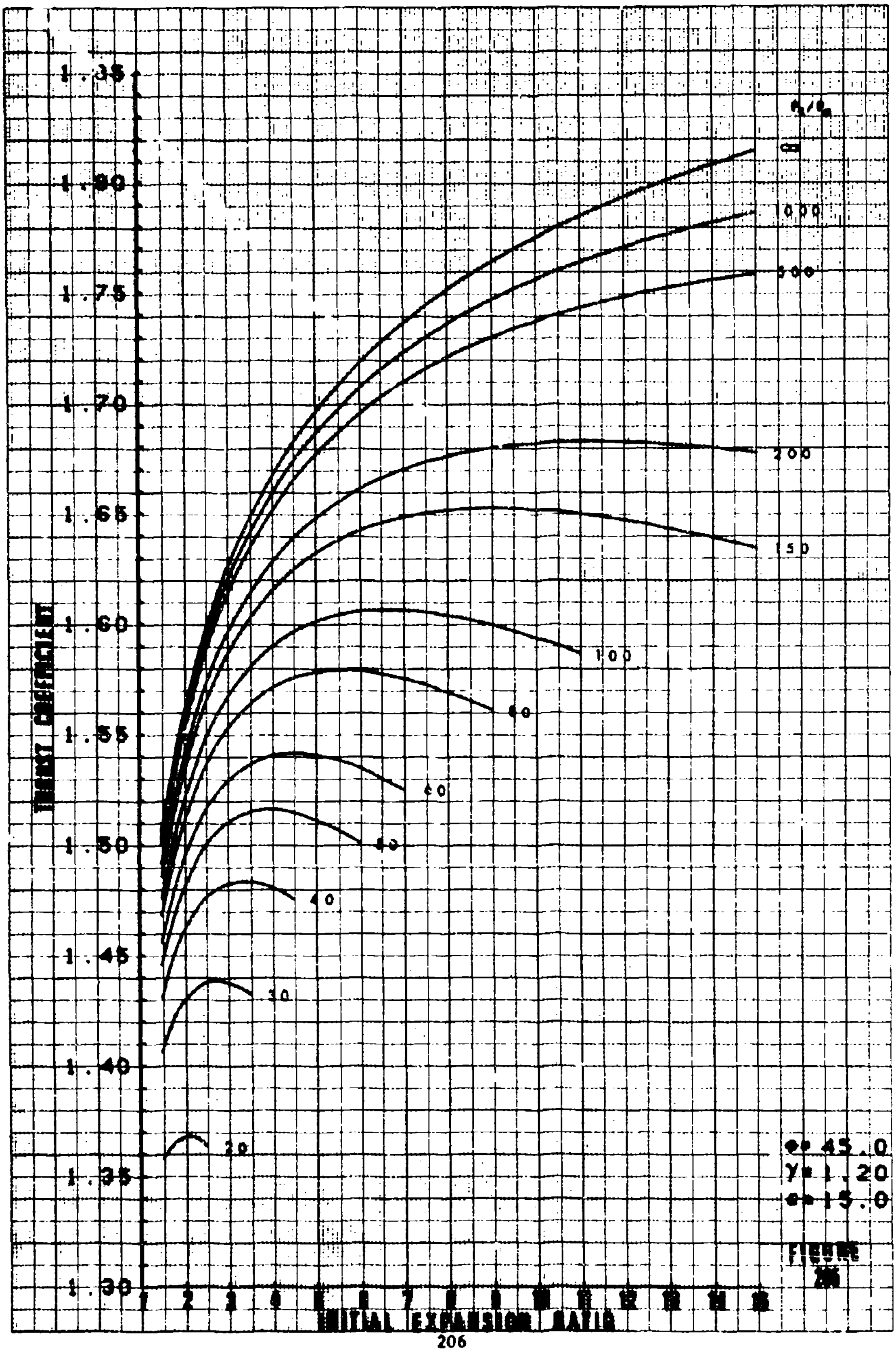
1.00
.75
.50
.25
0
-.25
-.50
-.75
-1.00
-1.25
-1.50
NON-DIMENSIONAL MOMENT
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
∞
1000
500
200
150
100
80
60
50
40
30
20
γ = 1.20
FIGURE 201

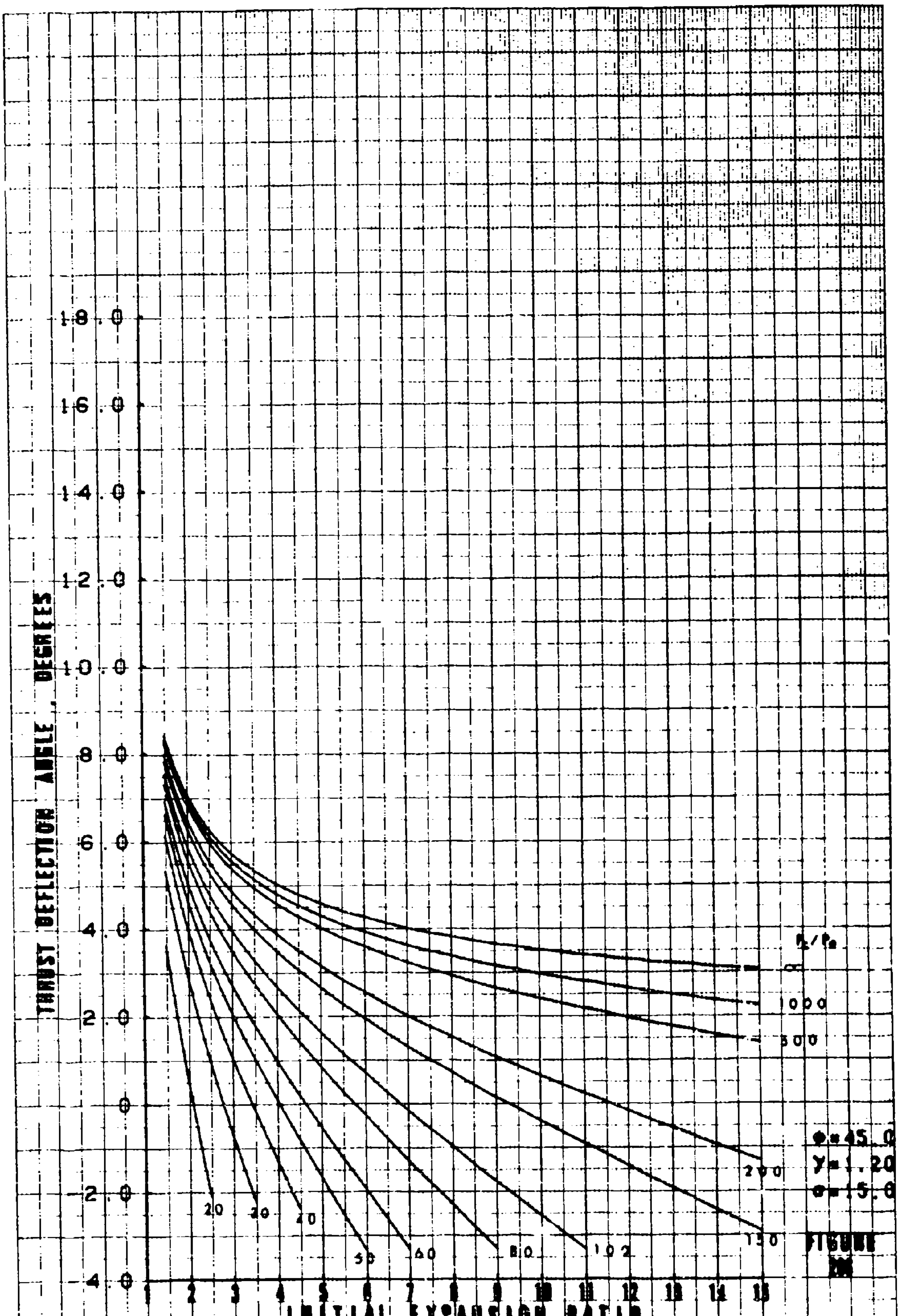

THRUST COEFFICIENT
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
INITIAL EXPANSION RATIO
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
P_c/P_a
∞
1000
500
200
150
100
80
60
50
40
30
20
Φ = 40.0
γ = 1.20
FIGURE 202


THRUST DEFLECTION ANGLE, DEGREES
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0
-2.0
-4.0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
INITIAL EXPANSION RATIO
∞
1000
500
200
150
100
80
60
50
40
30
20
= 40.0
γ = 1.20
= 15.0
FIGURE



NON-DIMENSIONAL MOMENT
INITIAL EXPANSION RATIO
2.00
1.50
1.00
.50
0
-.50
-1.00
-1.50
-2.00
-2.50
-3.00
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
1000
500
300
200
150
100
80
60
50
40
30
20
FIGURE


THRUST COEFFICIENT
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
INITIAL EXPANSION RATIO
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
1000
500
200
150
100
80
60
50
40
30
20
γ= 1.20
FIGURE



18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0
-2.0
-4.0
THRUST DEFLECTION ANGLE, DEGREES
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
1000
500
200
150
102
80
60
50
40
30
20

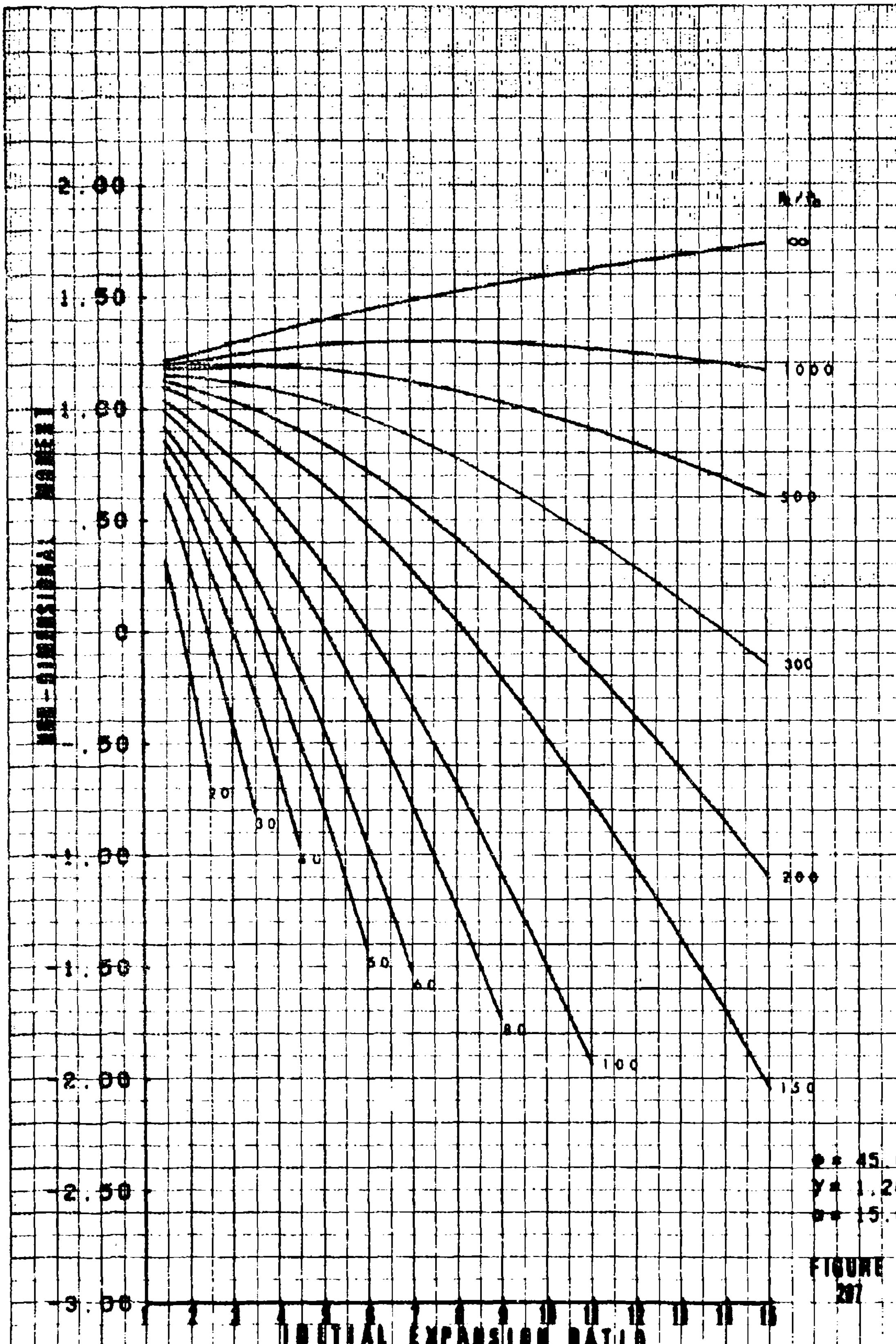
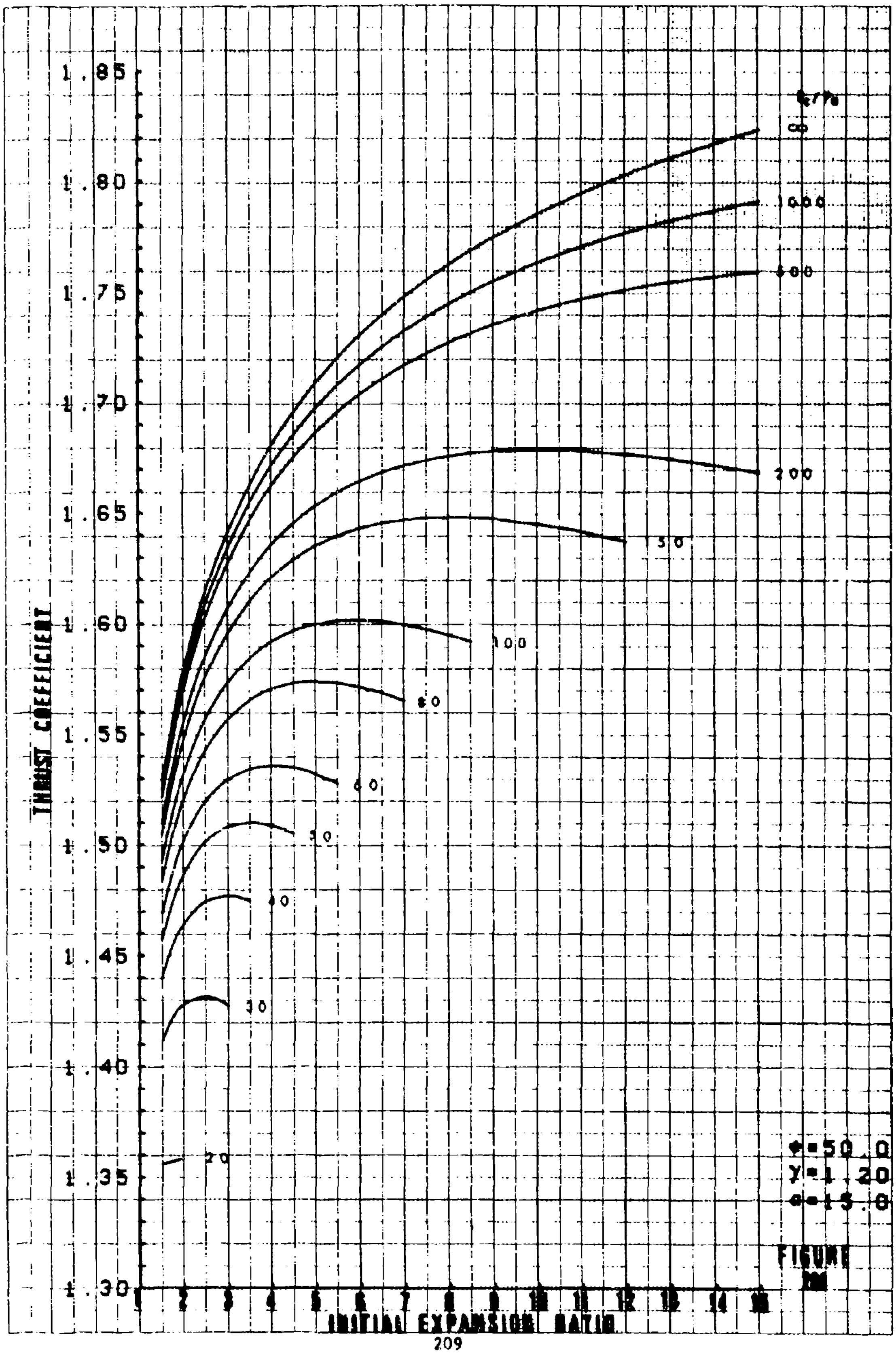
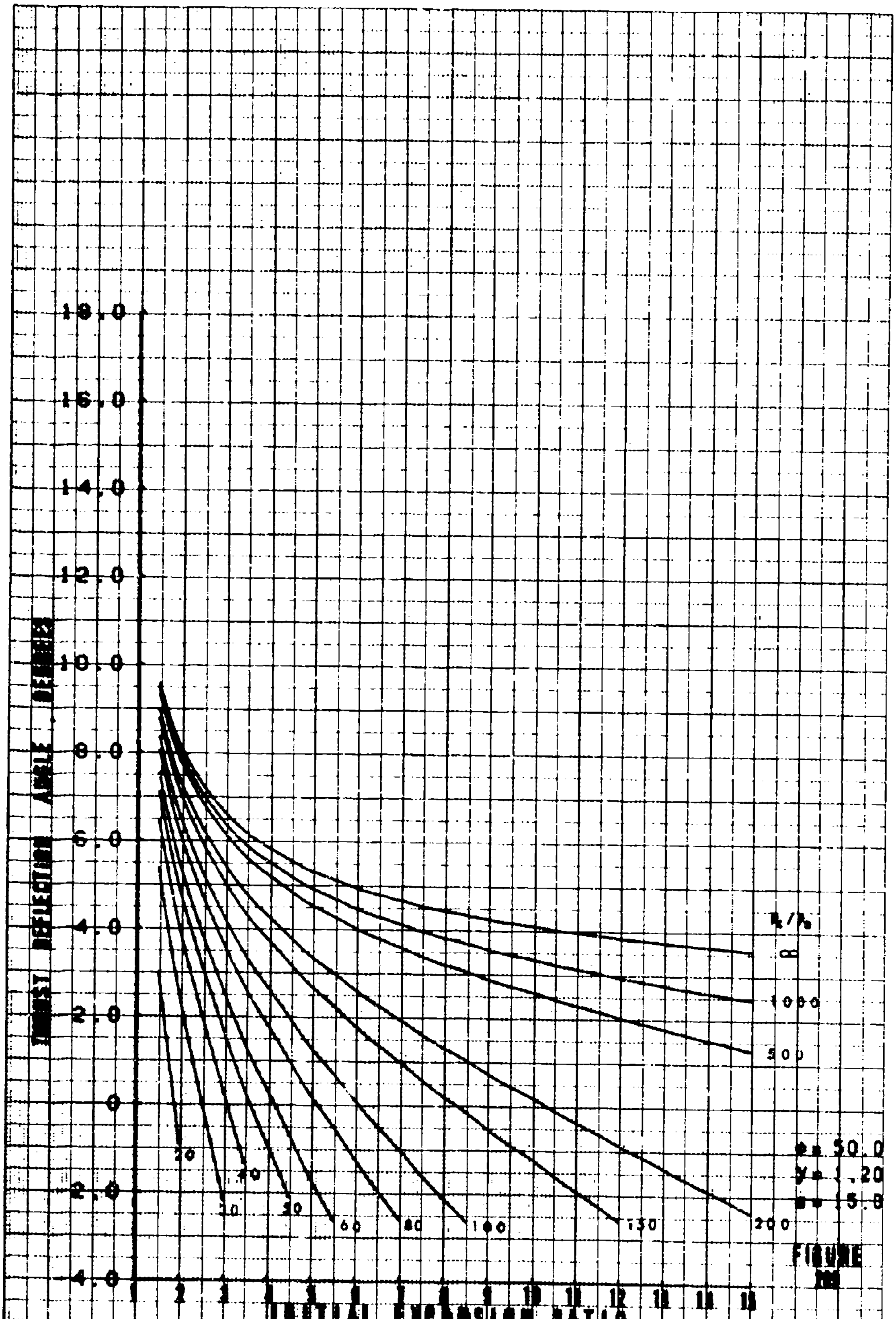
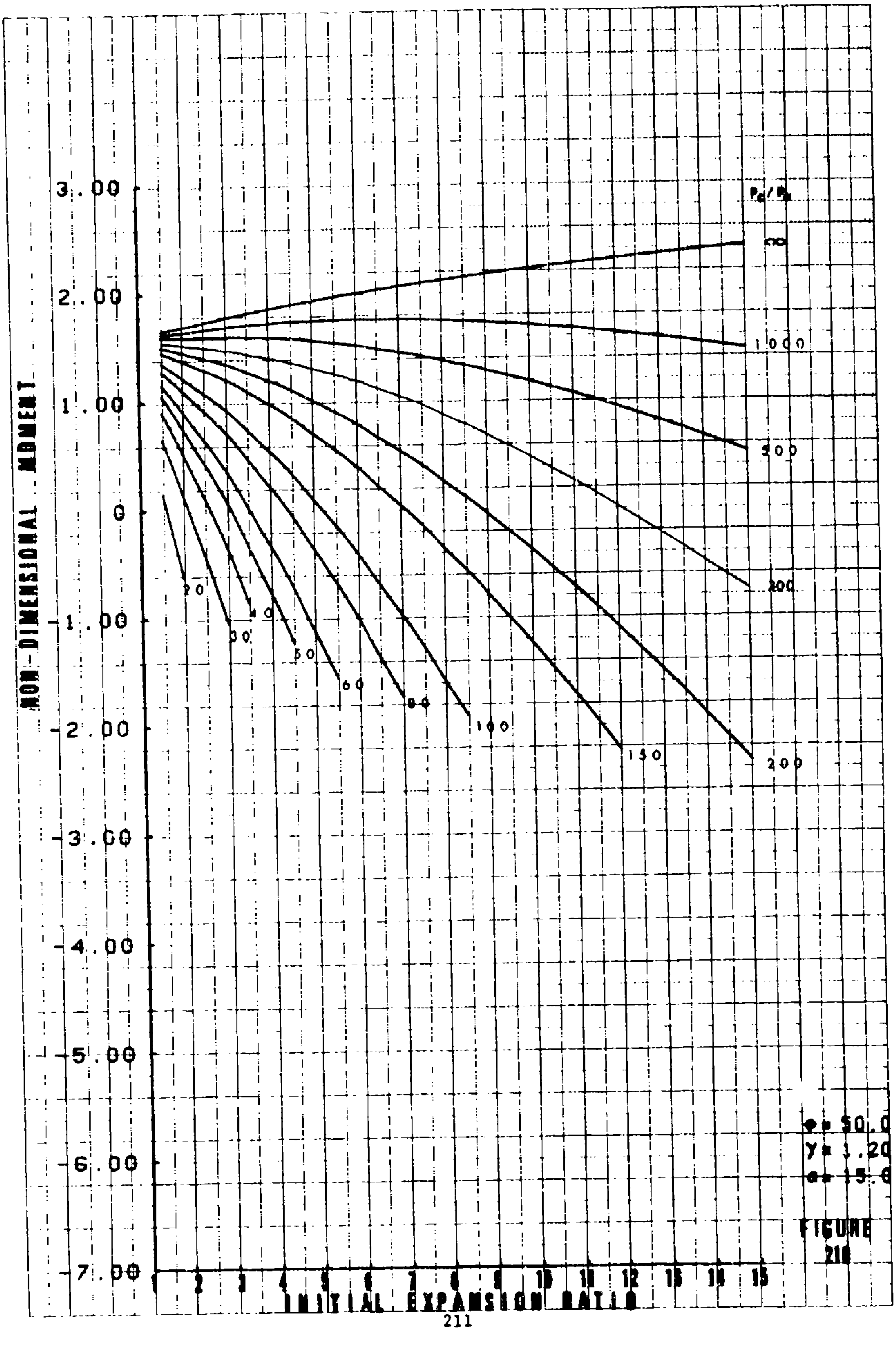

2.00
1.50
1.00
.50
0
-.50
-1.00
-1.50
-2.00
-2.50
-3.00
NON-DIMENSIONAL MOMENT
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
∞
1000
500
300
200
150
100
80
60
50
40
30
20
θ= 45.0
γ= 1.20
ν= 15.0

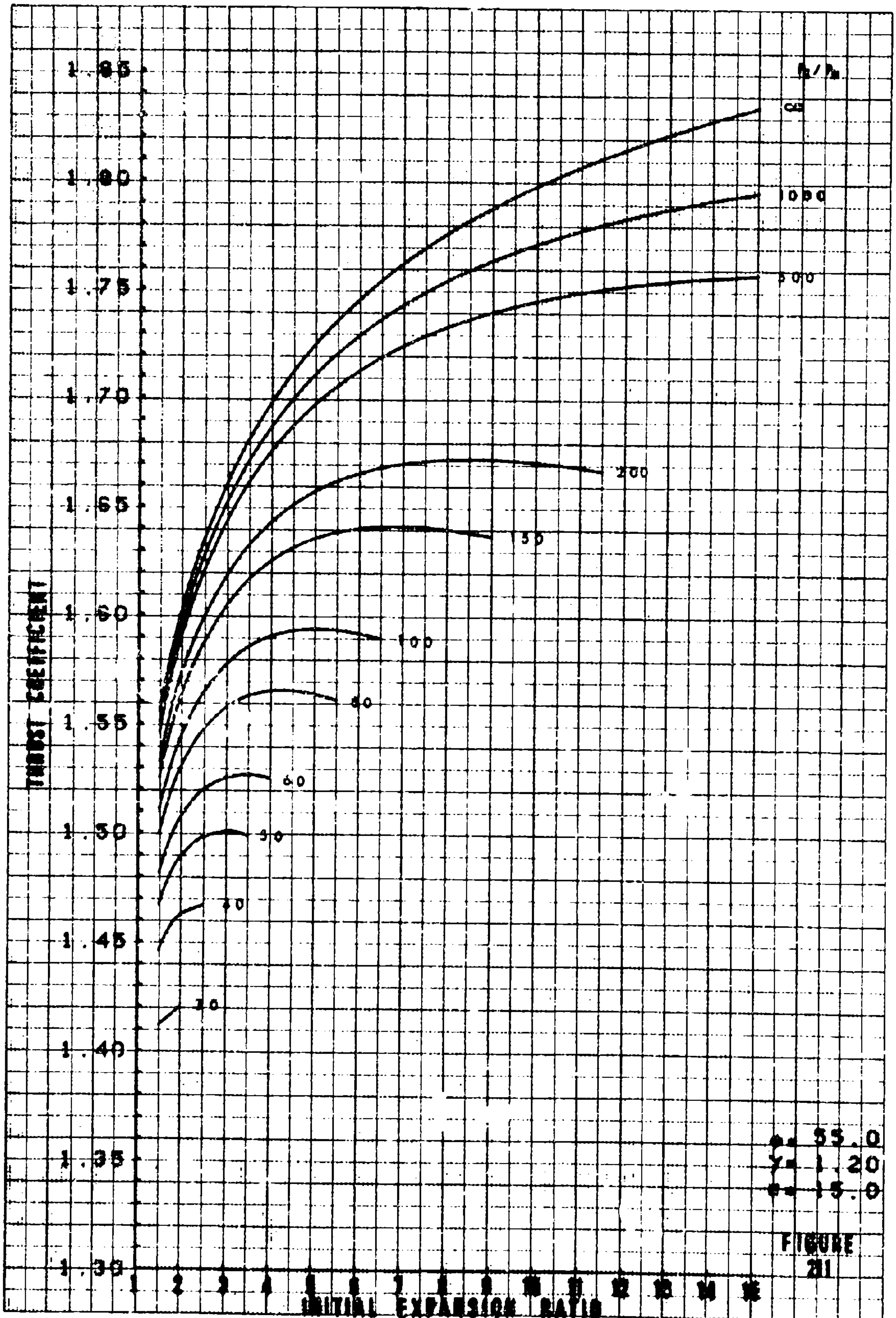
FIGURE 207


THRUST COEFFICIENT
INITIAL EXPANSION RATIO
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
∞
1000
500
200
150
100
80
60
50
40
30
20
φ=50.0
γ=1.20
FIGURE


18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0
-2.0
-4.0
1
2
3
20
30
40
50
60
80
100
150
200
500
1000

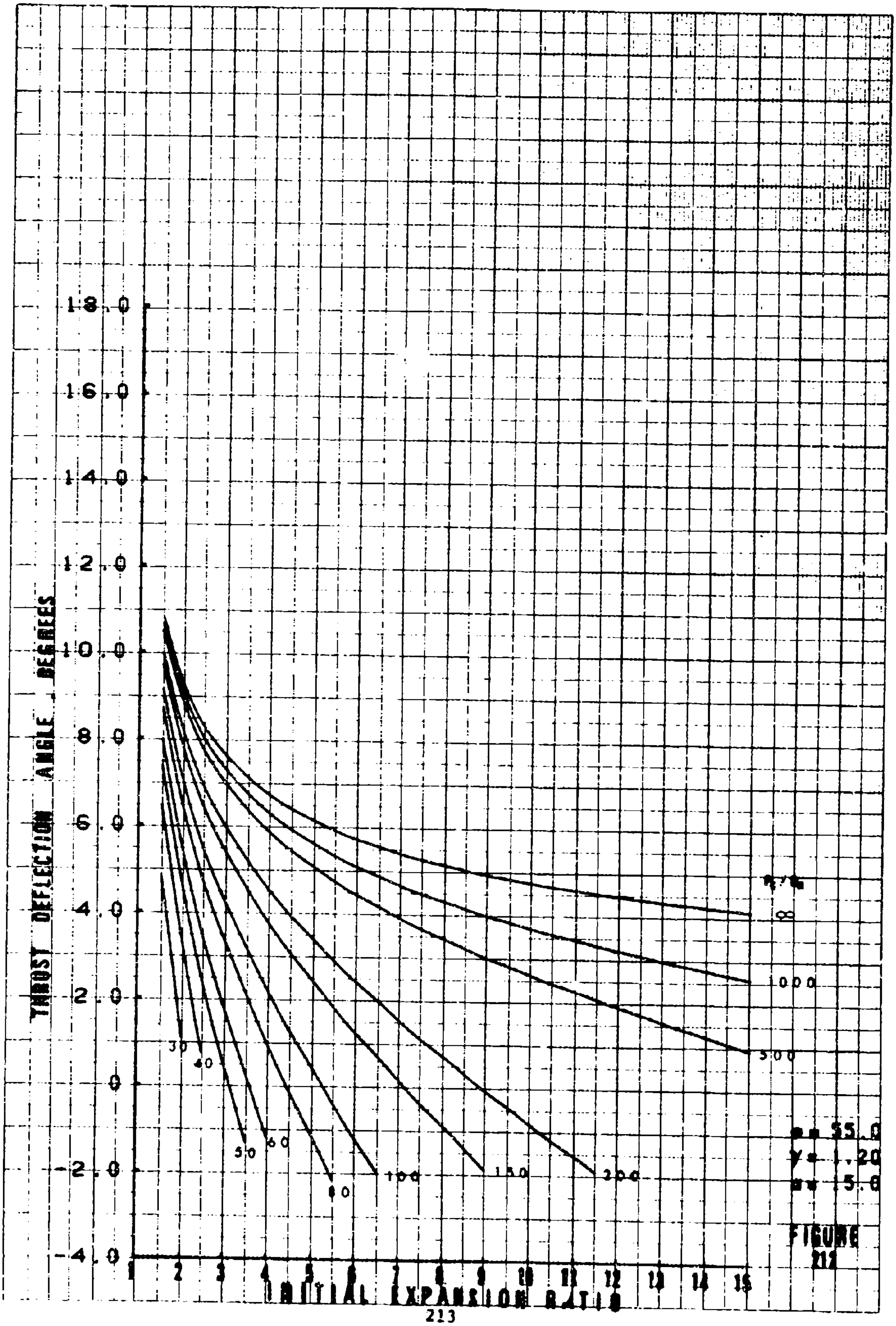


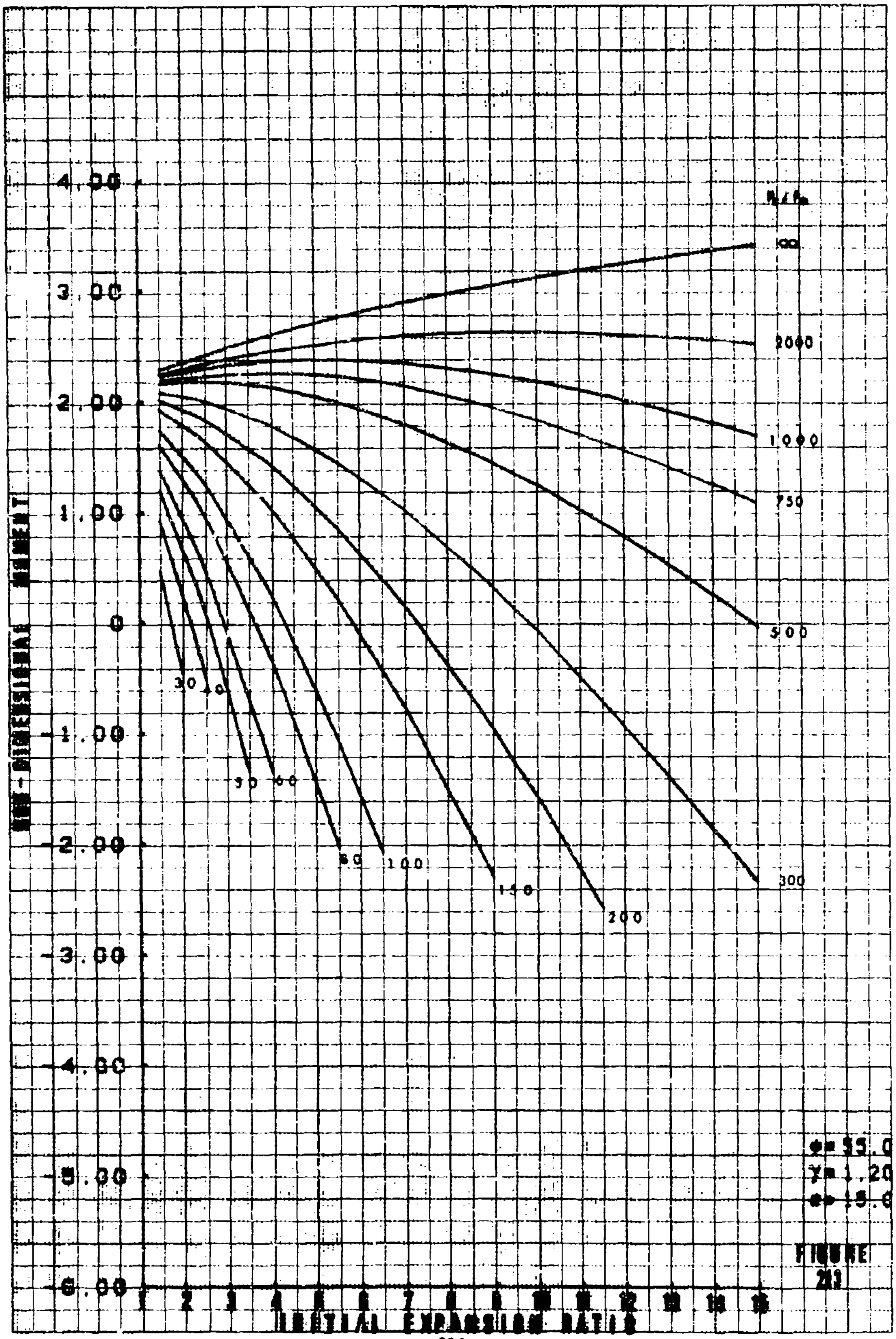
NON-DIMENSIONAL MOMENT
3.00
2.00
1.00
0
-1.00
-2.00
-3.00
-4.00
-5.00
-6.00
-7.00
P_c/P_a
∞
1000
500
300
200
150
100
80
60
50
40
30
20
φ= 50.
γ= 1.20
α= 15.
FIGURE
218
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO



THRUST COEFFICIENT
INITIAL EXPANSION RATIO
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
P_c/P_a
∞
1000
500
200
150
100
80
60
50
40
30
θ= 55.0
γ= 1.20
α= 15.0

FIGURE 211


THRUST DEFLECTION ANGLE, DEGREES
INITIAL EXPANSION RATIO
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0
-2.0
-4.0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
30
40
50
60
80
100
150
200
500
1000
∞
1.20
5.0
FIGURE 212


4.00
3.00
2.00
1.00
0
-1.00
-2.00
-3.00
-4.00
-5.00
-6.00
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
2000
1000
750
500
300
30
40
50
60
80
100
150
200
FIGURE
213

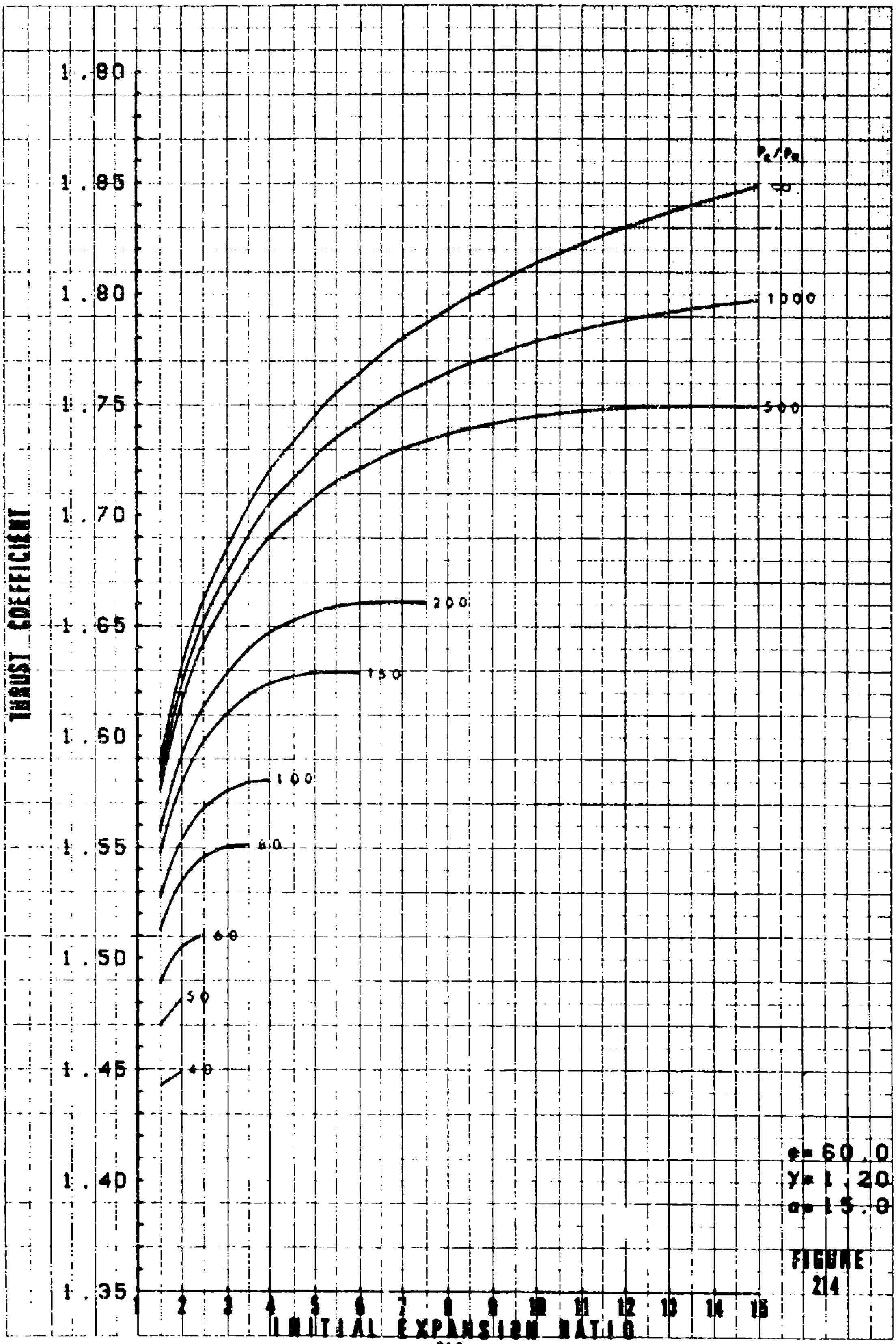
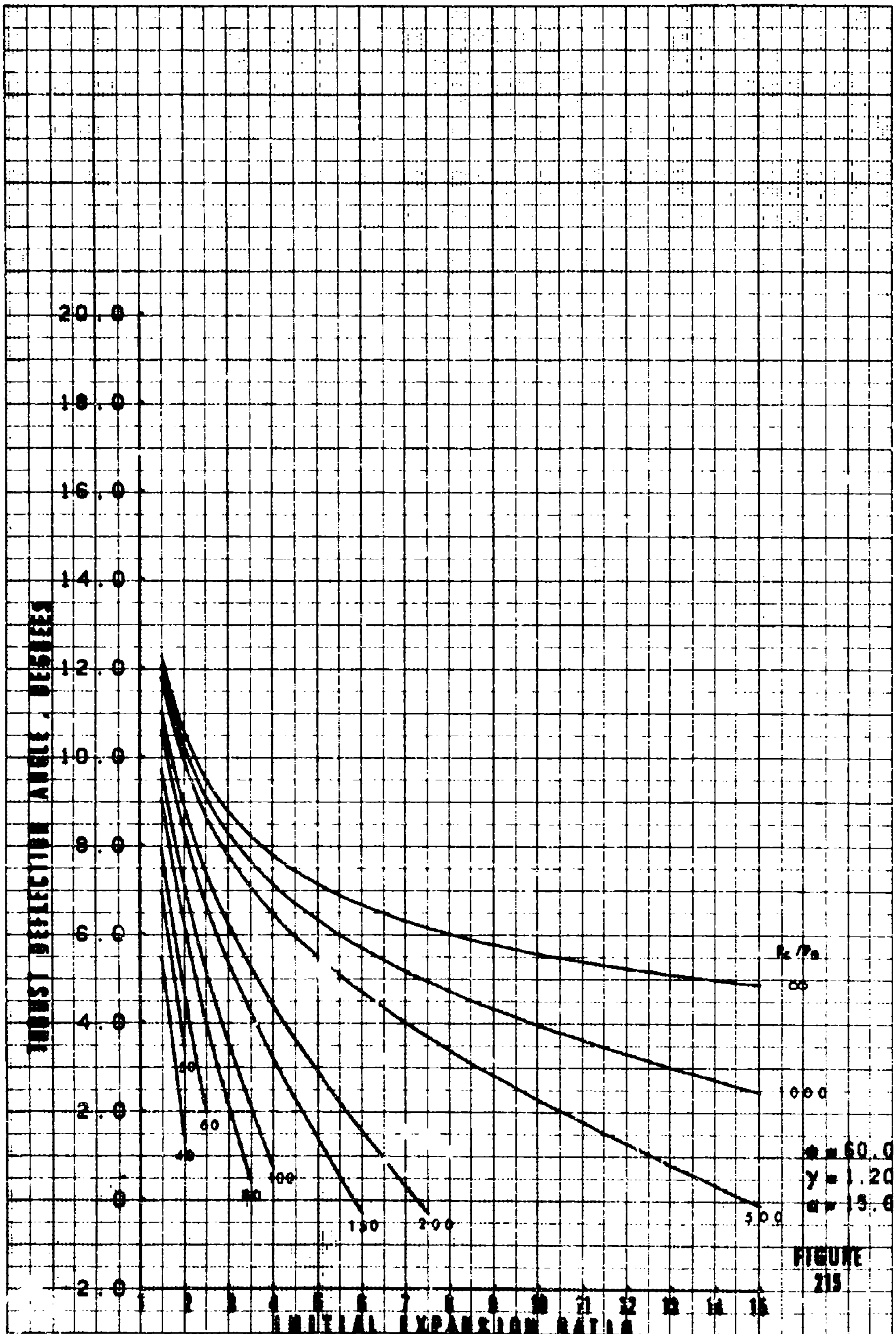
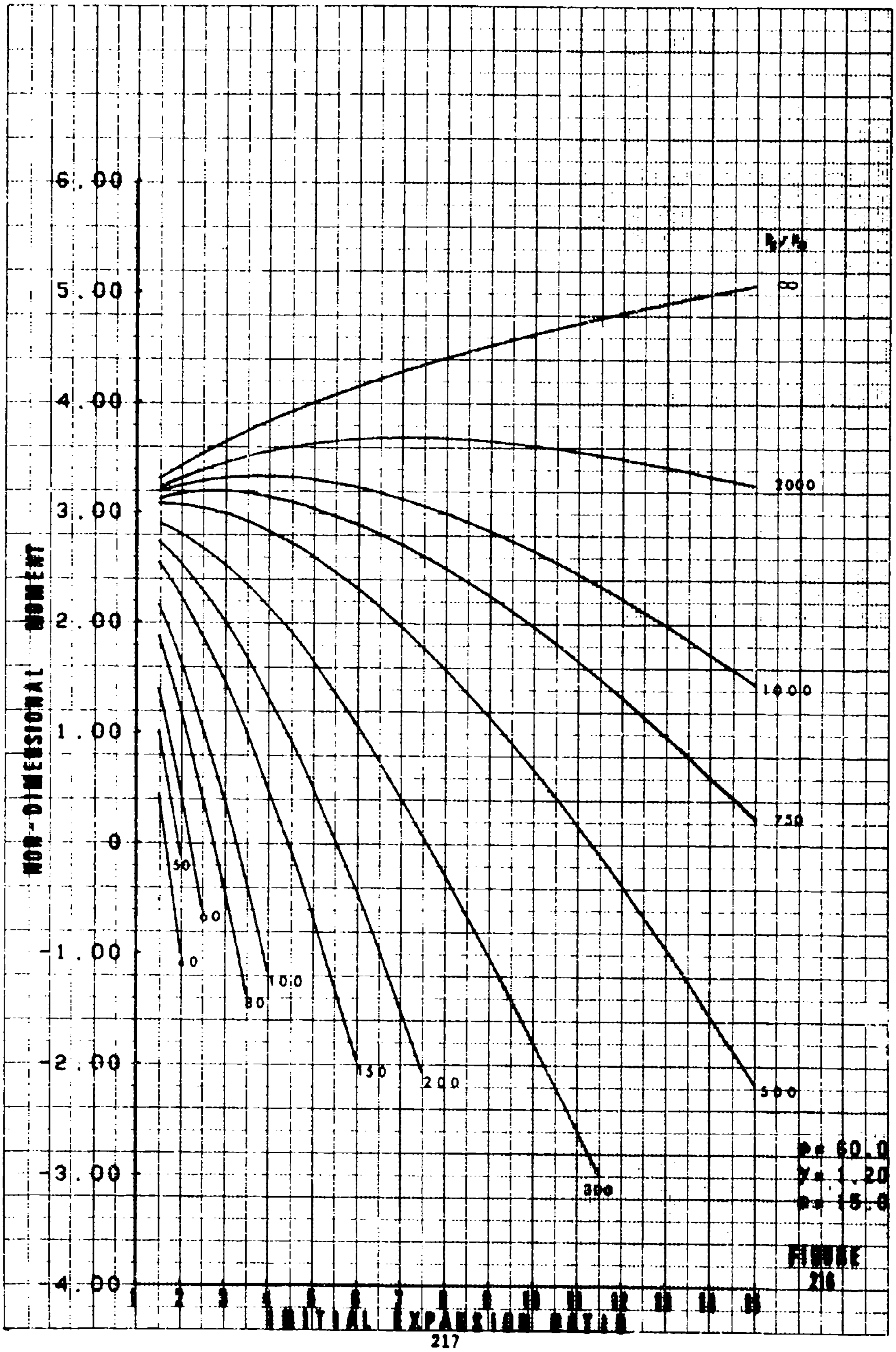
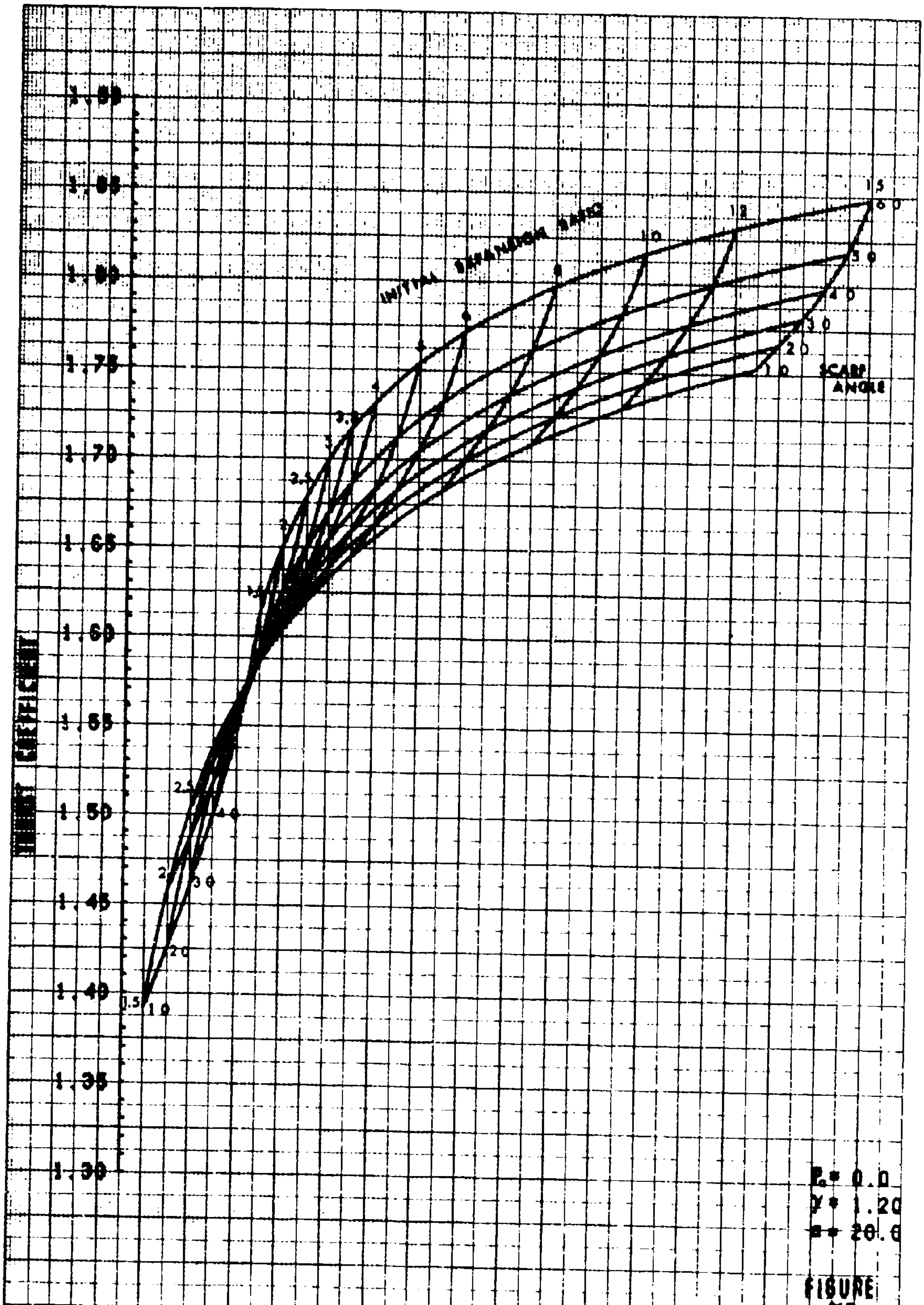

THRUST COEFFICIENT
1.80
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
INITIAL EXPANSION RATIO
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
P_c/P_a
∞
1000
500
200
150
100
80
60
50
40
e= 60.0
γ= 1.20
α= 15.0

FIGURE 214

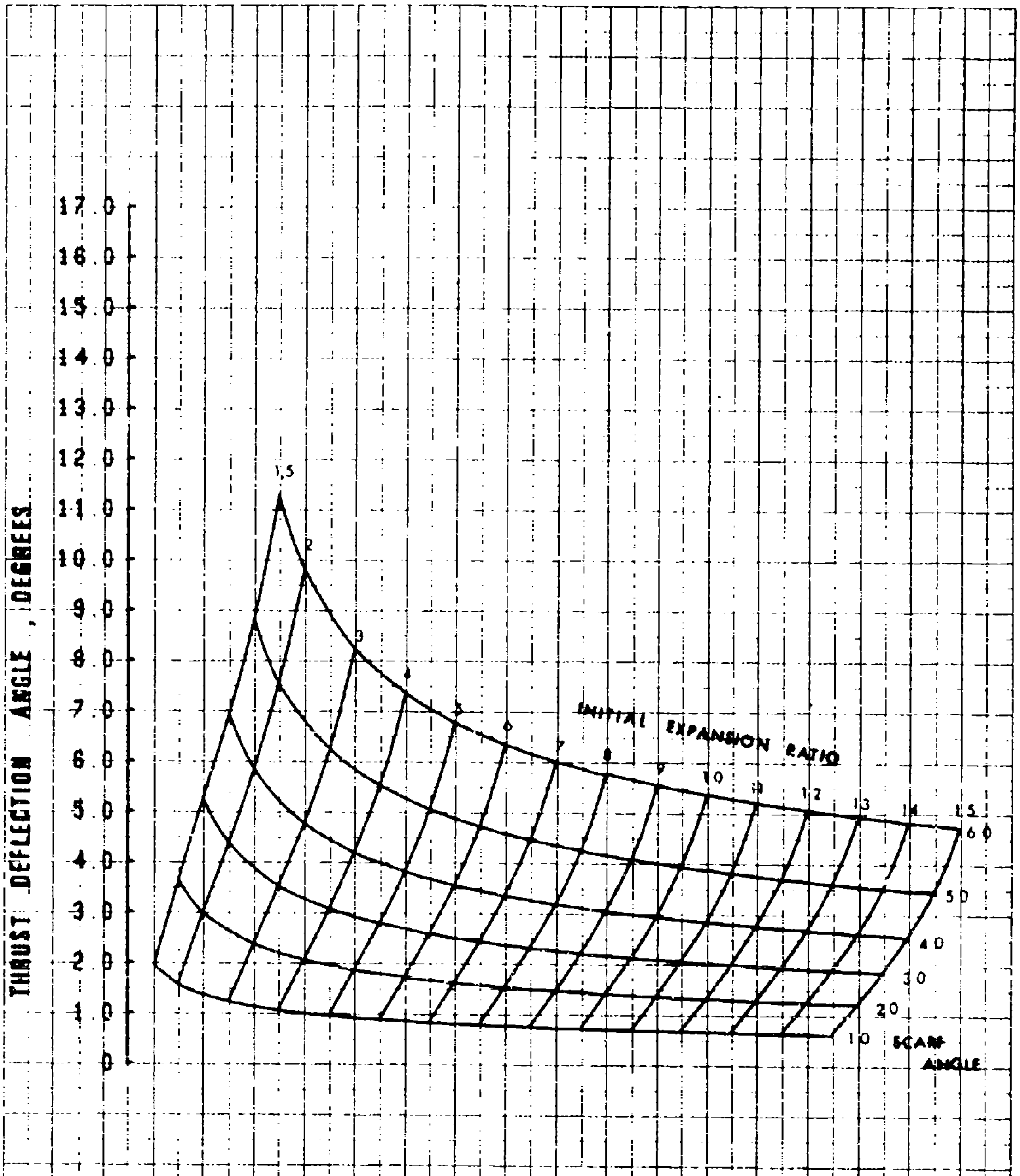

THRUST DEFLECTION ANGLE, DEGREES
INITIAL EXPANSION RATIO
20.0
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0
2.0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
P_c/P_a
∞
1000
500
200
150
100
80
60
40
40
60.0
γ = 1.20
FIGURE 215


NON-DIMENSIONAL MOMENT
6.00
5.00
4.00
3.00
2.00
1.00
0
-1.00
-2.00
-3.00
-4.00
∞
2000
1000
750
500
300
200
150
100
80
60
50
40
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
FIGURE
216

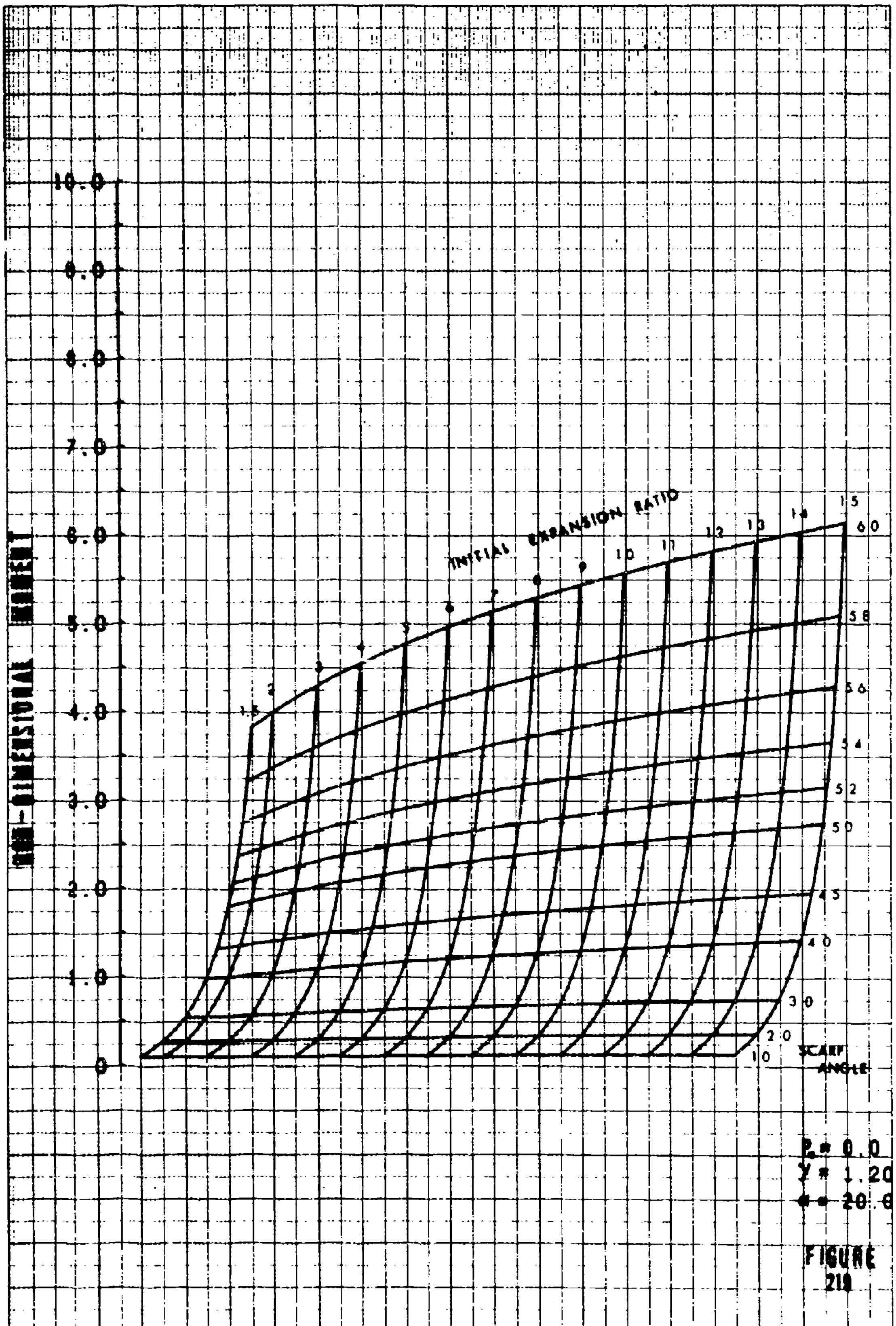


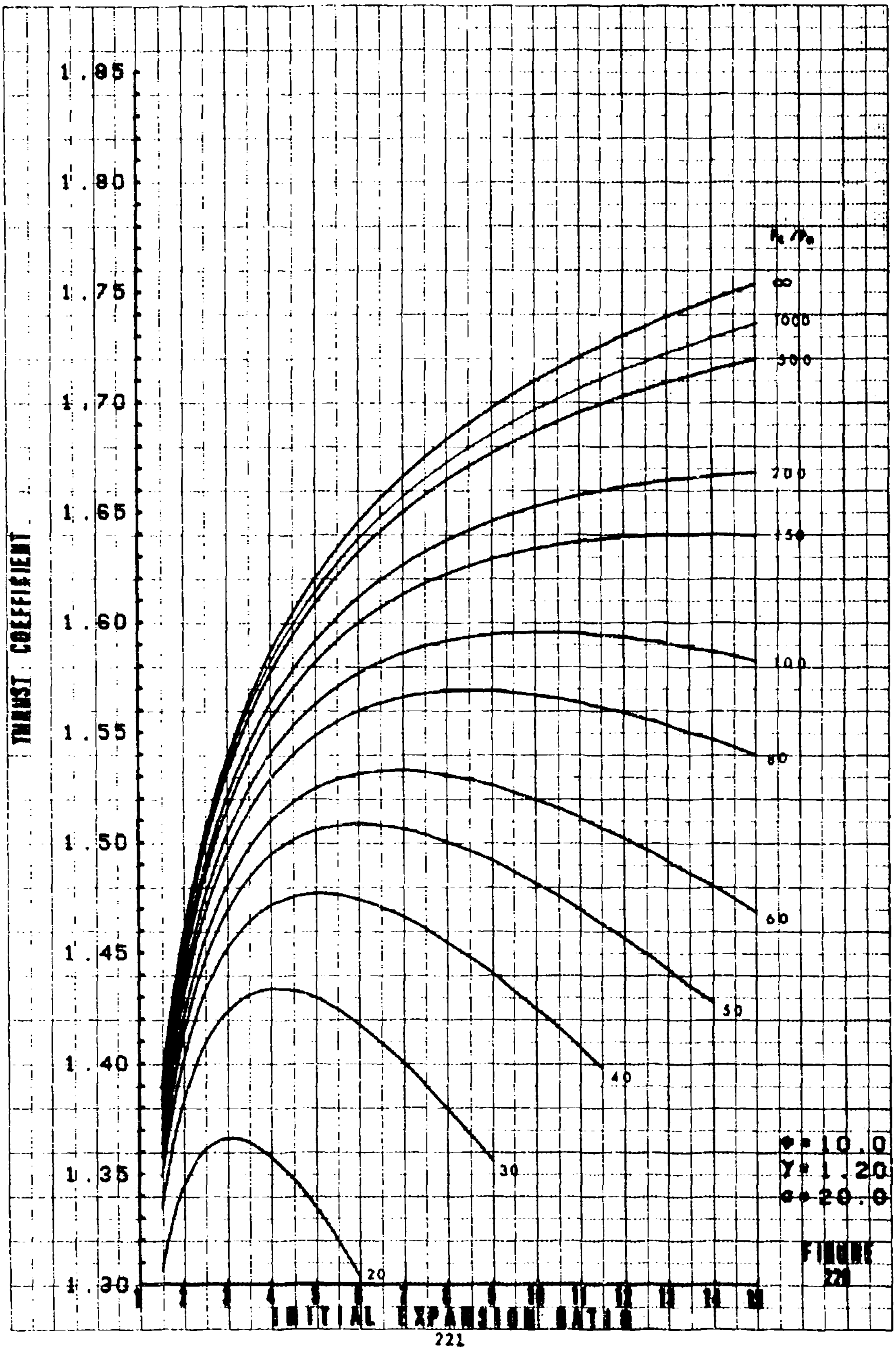
INITIAL EXPANSION RATIO
SCARF ANGLE
THRUST COEFFICIENT
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30

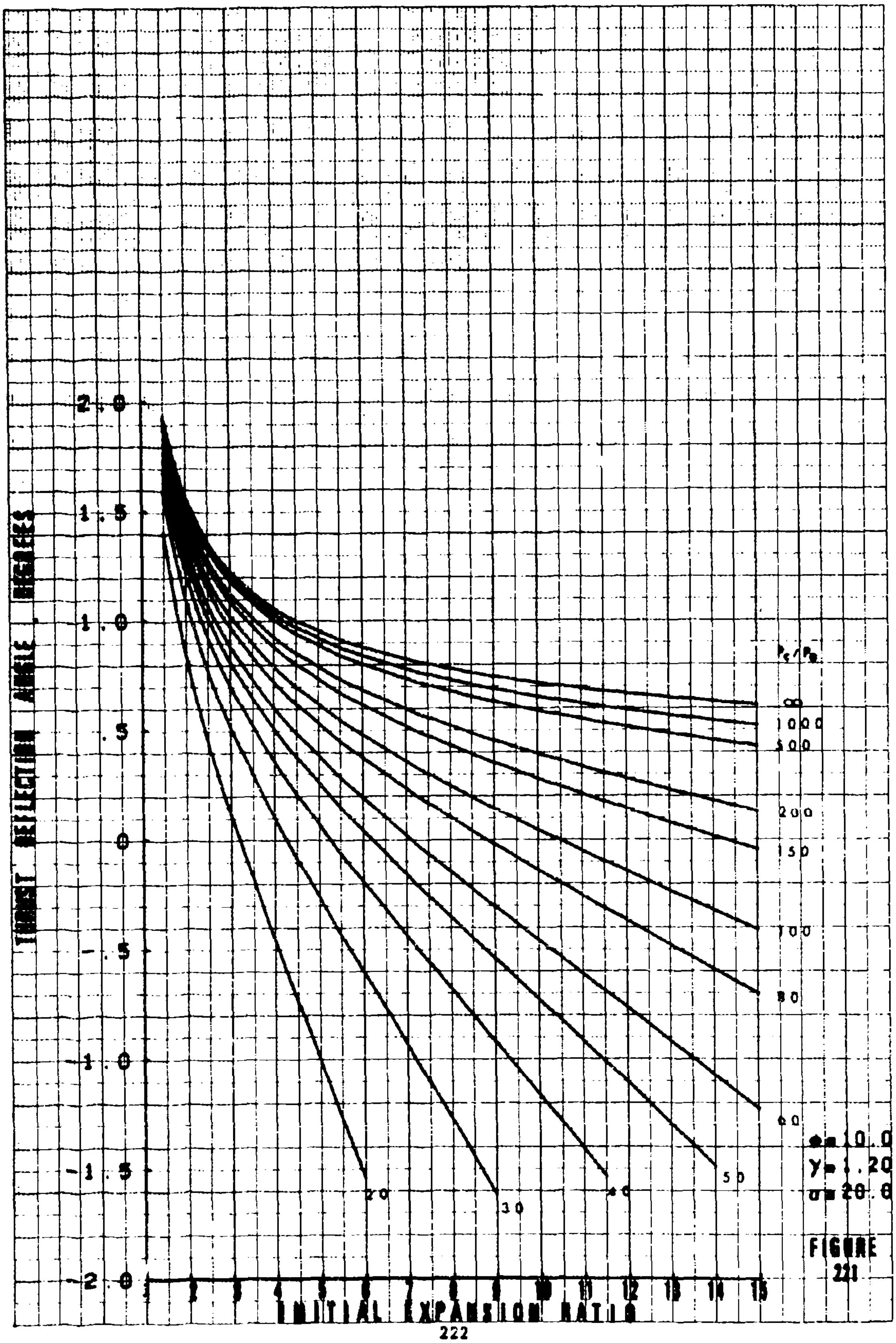
FIGURE 217

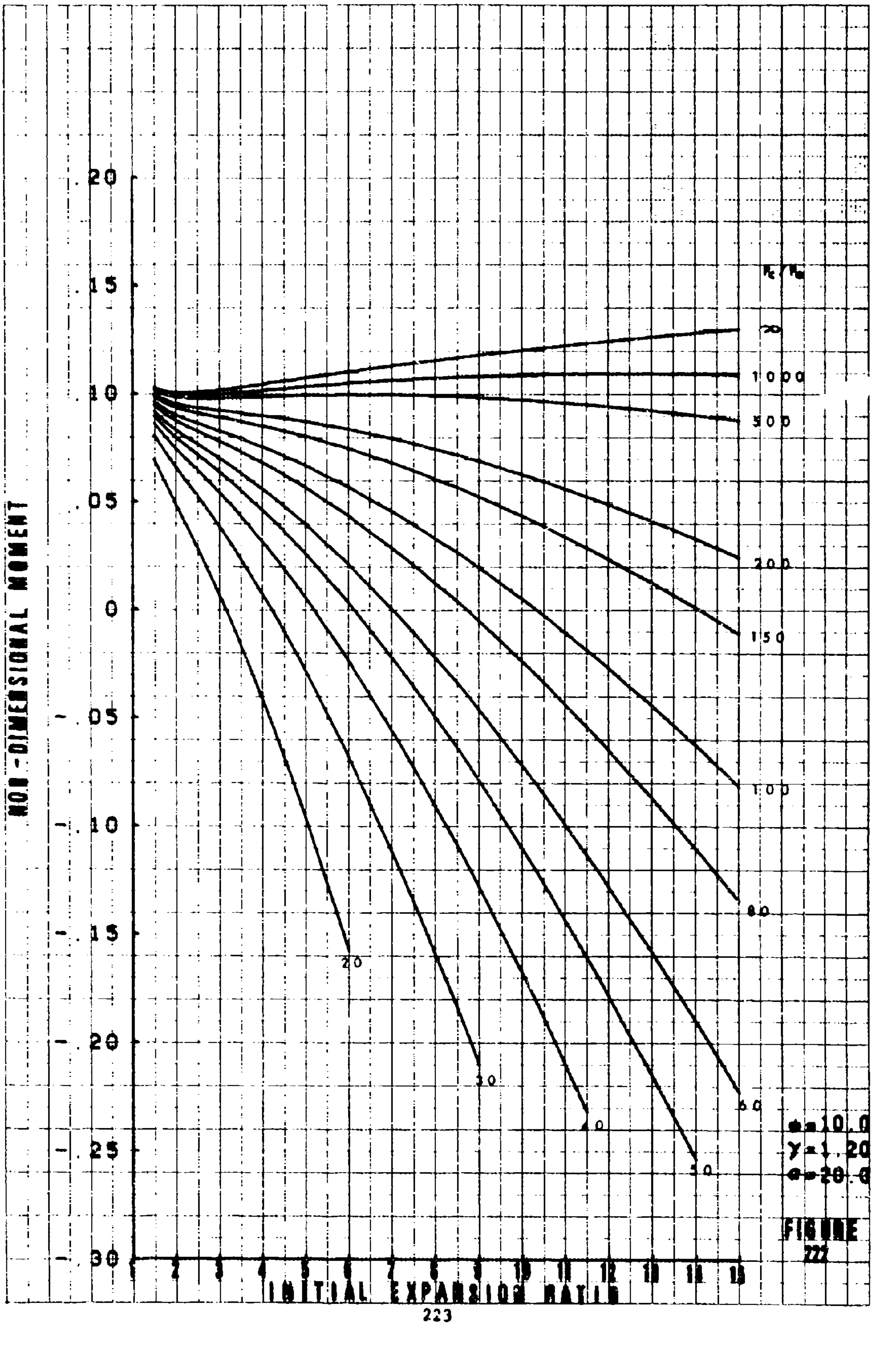


THRUST DEFLECTION ANGLE, DEGREES
INITIAL EXPANSION RATIO
SCARF ANGLE
17.0
16.0
15.0
14.0
13.0
12.0
11.0
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
1.5
2
3
4
5
6
7
8
9
10
11
12
13
14
15
60
50
40
30
20
10
1.20
FIGURE
218


NON-DIMENSIONAL MOMENT
INITIAL EXPANSION RATIO
SCARF ANGLE
10.0
6.0
5.0
4.0
3.0
2.0
1.0
0
60
58
56
54
52
50
45
40
30
20
10
FIGURE
219

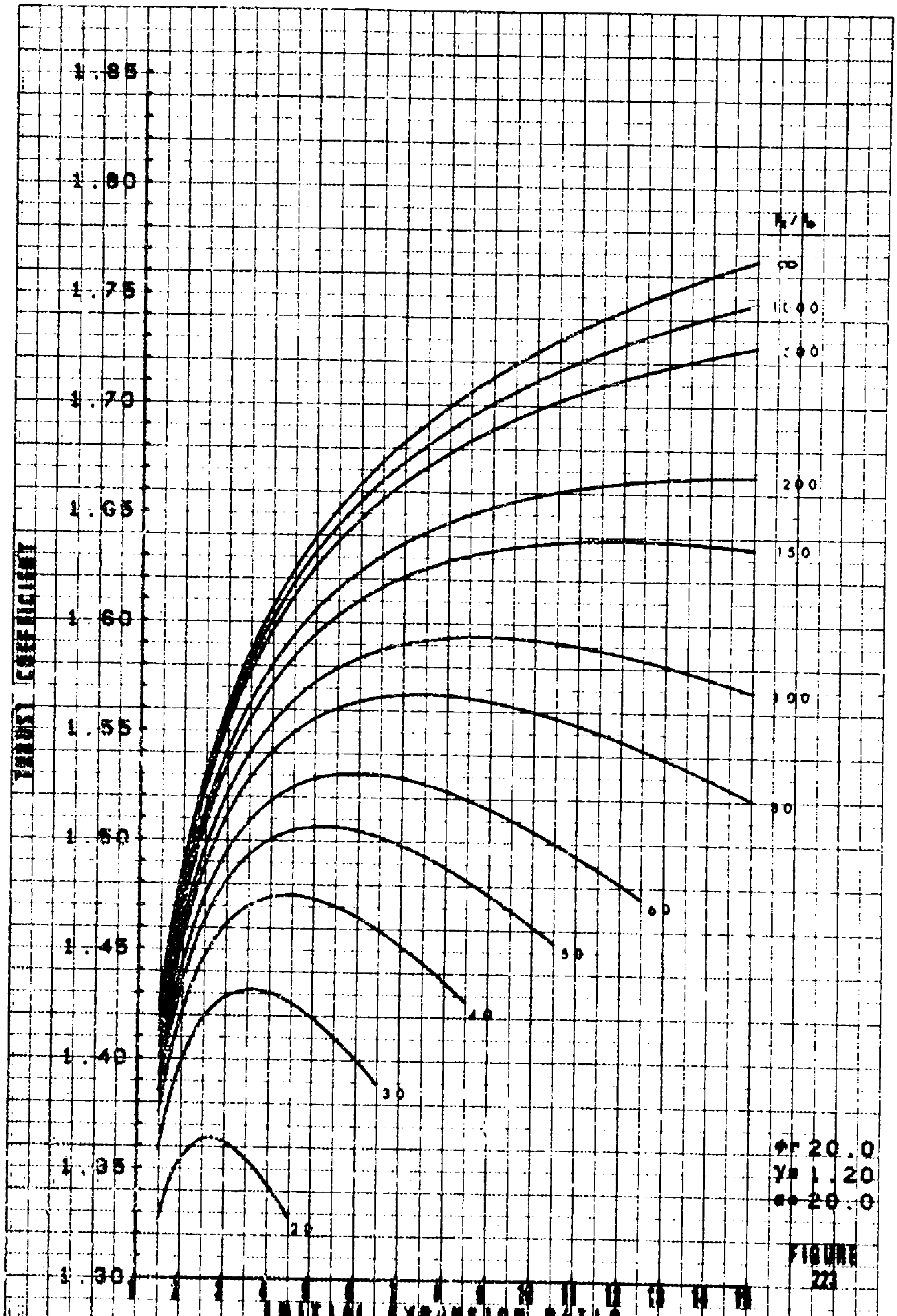

THRUST COEFFICIENT
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
INITIAL EXPANSION RATIO
∞
1000
500
200
150
100
80
60
50
40
30
20
10.0
1.20
20.0


THRUST DEFLECTION ANGLE, DEGREES
2.0
1.5
1.0
.5
0
-.5
-1.0
-1.5
-2.0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
P_c/P_a
∞
1000
500
200
150
100
80
60
50
40
30
20
φ = 10.0
γ = 1.20
α = 20.0
FIGURE 221



NON-DIMENSIONAL MOMENT
.20
.15
.10
.05
0
-.05
-.10
-.15
-.20
-.25
-.30
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
INITIAL EXPANSION RATIO
P_c/P_a
∞
1000
500
200
150
100
80
60
50
40
30
20
φ=10.0
γ=1.20
α=20.0

FIGURE 222


THRUST COEFFICIENT
INITIAL EXPANSION RATIO
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
∞
1000
500
200
150
100
80
60
50
40
30
20
γ = 1.20
FIGURE
223

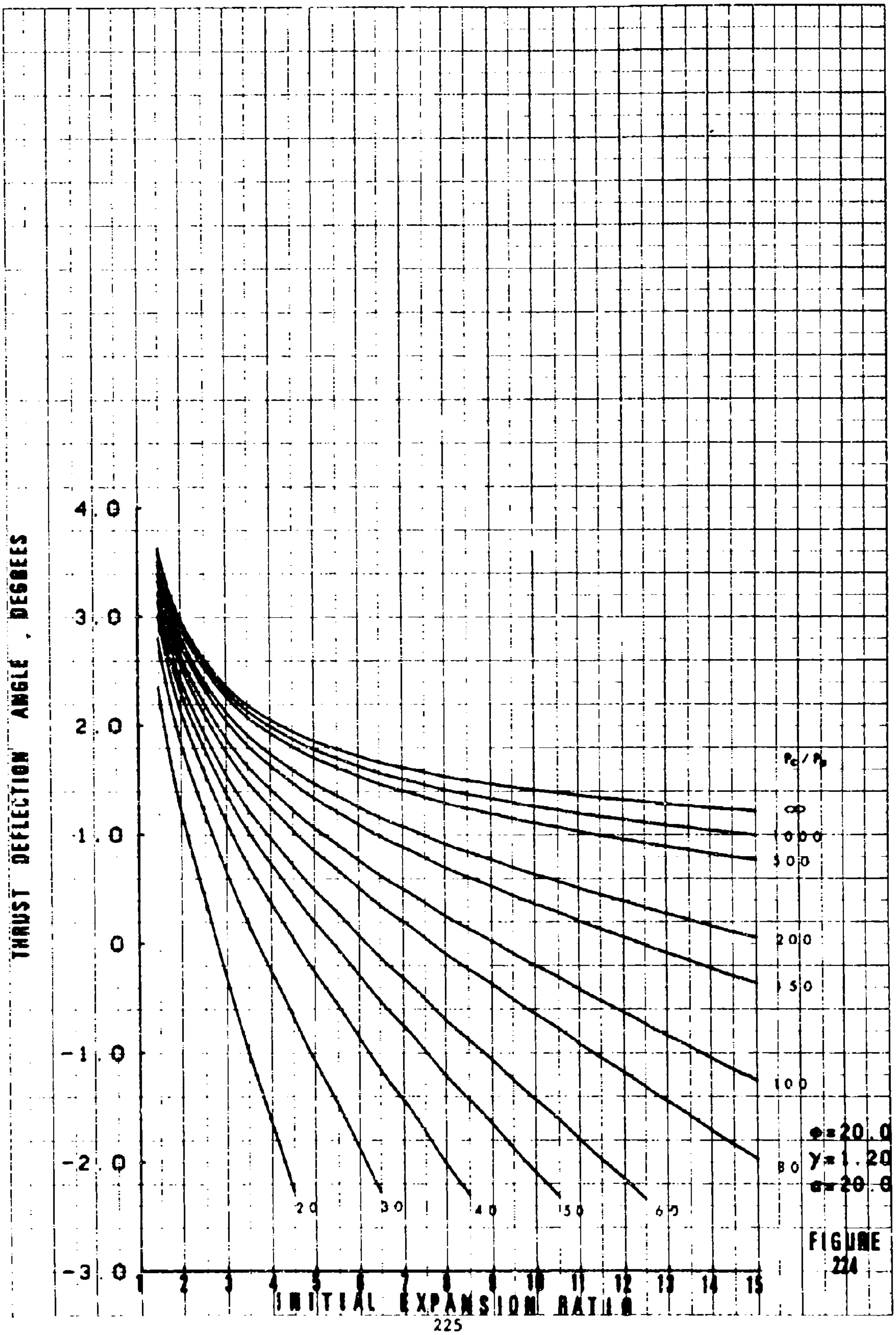
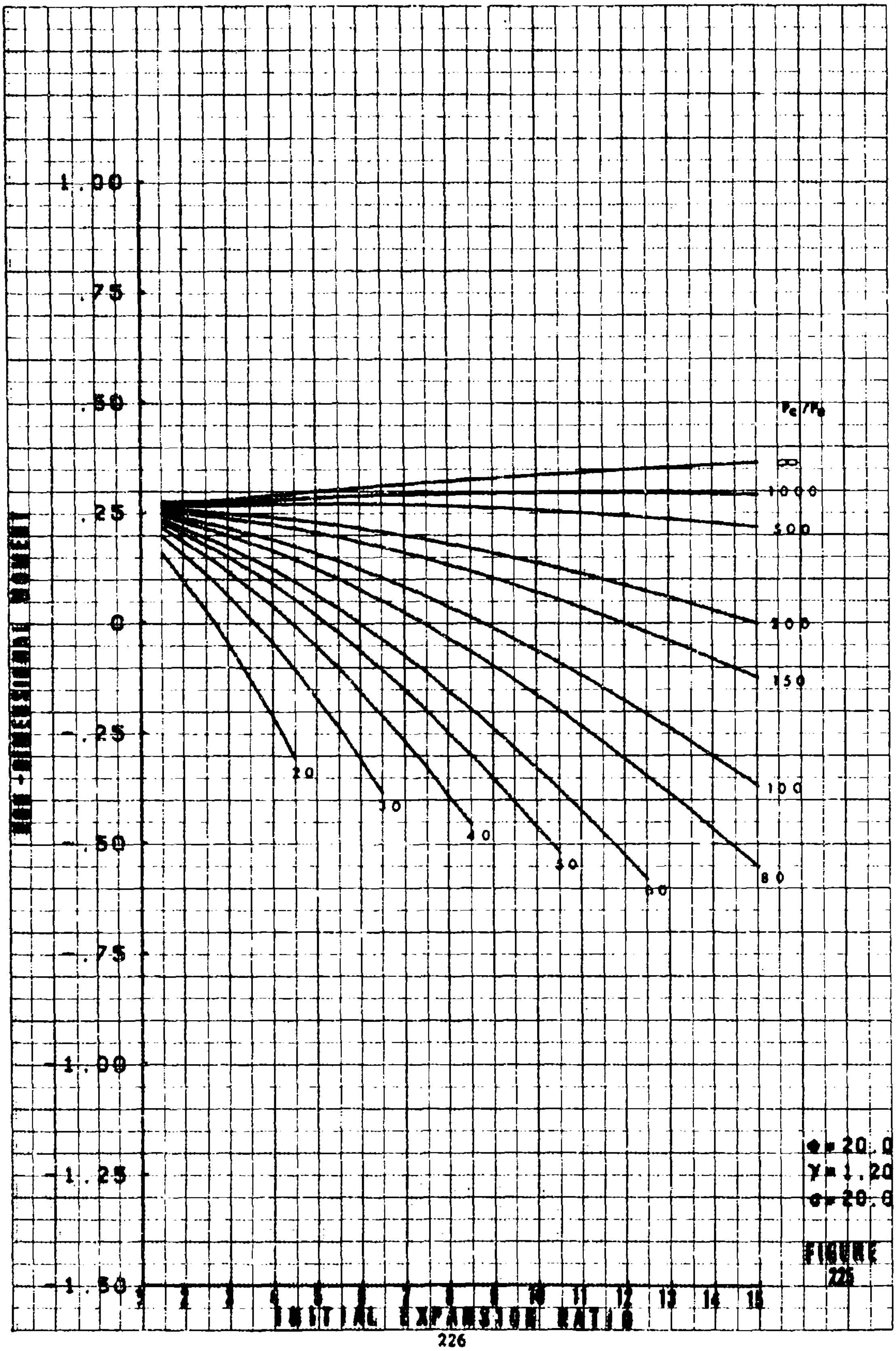

THRUST DEFLECTION ANGLE, DEGREES
4.0
3.0
2.0
1.0
0
-1.0
-2.0
-3.0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
P_c/P_a
∞
1000
500
200
150
100
80
20
30
40
50
65
φ=20.0
γ=1.20
α=20.0

FIGURE 224



NON-DIMENSIONAL MOMENT
INITIAL EXPANSION RATIO
P_c/P_a
∞
1000
500
200
150
100
80
60
50
40
30
20
φ = 20.0
γ = 1.20
σ = 20.0

FIGURE 225

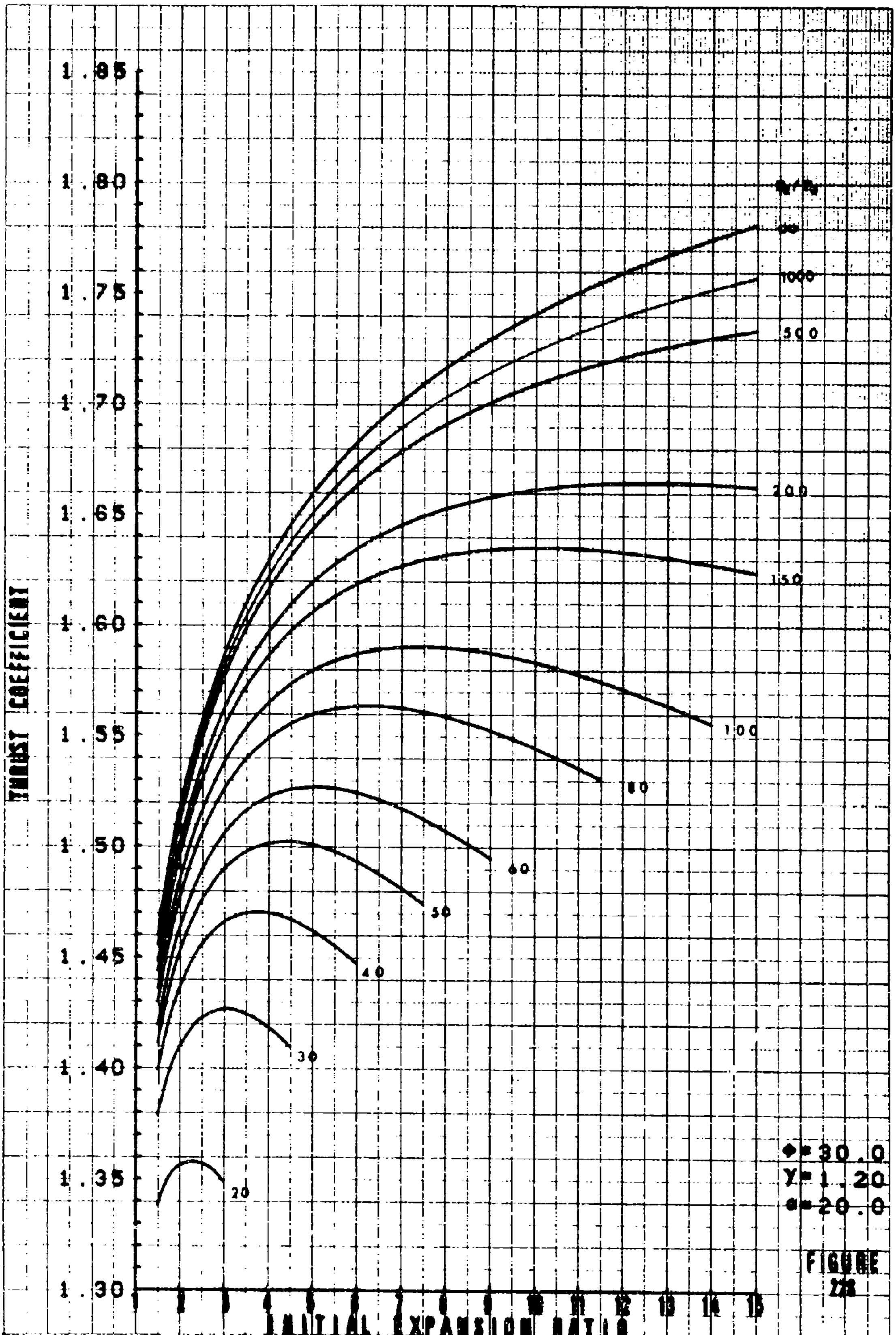

THRUST COEFFICIENT
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
INITIAL EXPANSION RATIO
1000
500
200
150
100
80
60
50
40
30
20
Φ=30.0
γ=1.20
α=20.0

FIGURE 228

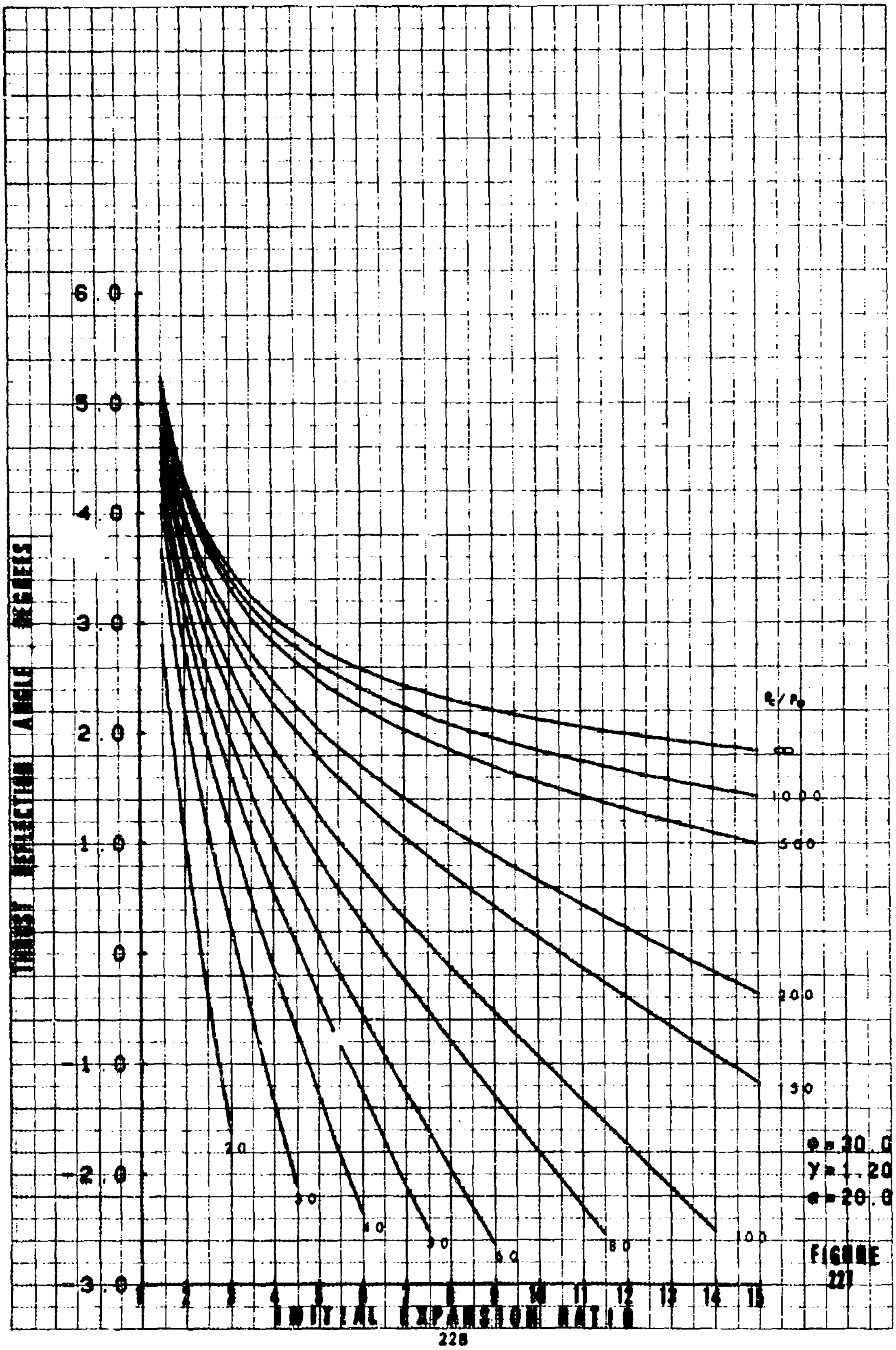
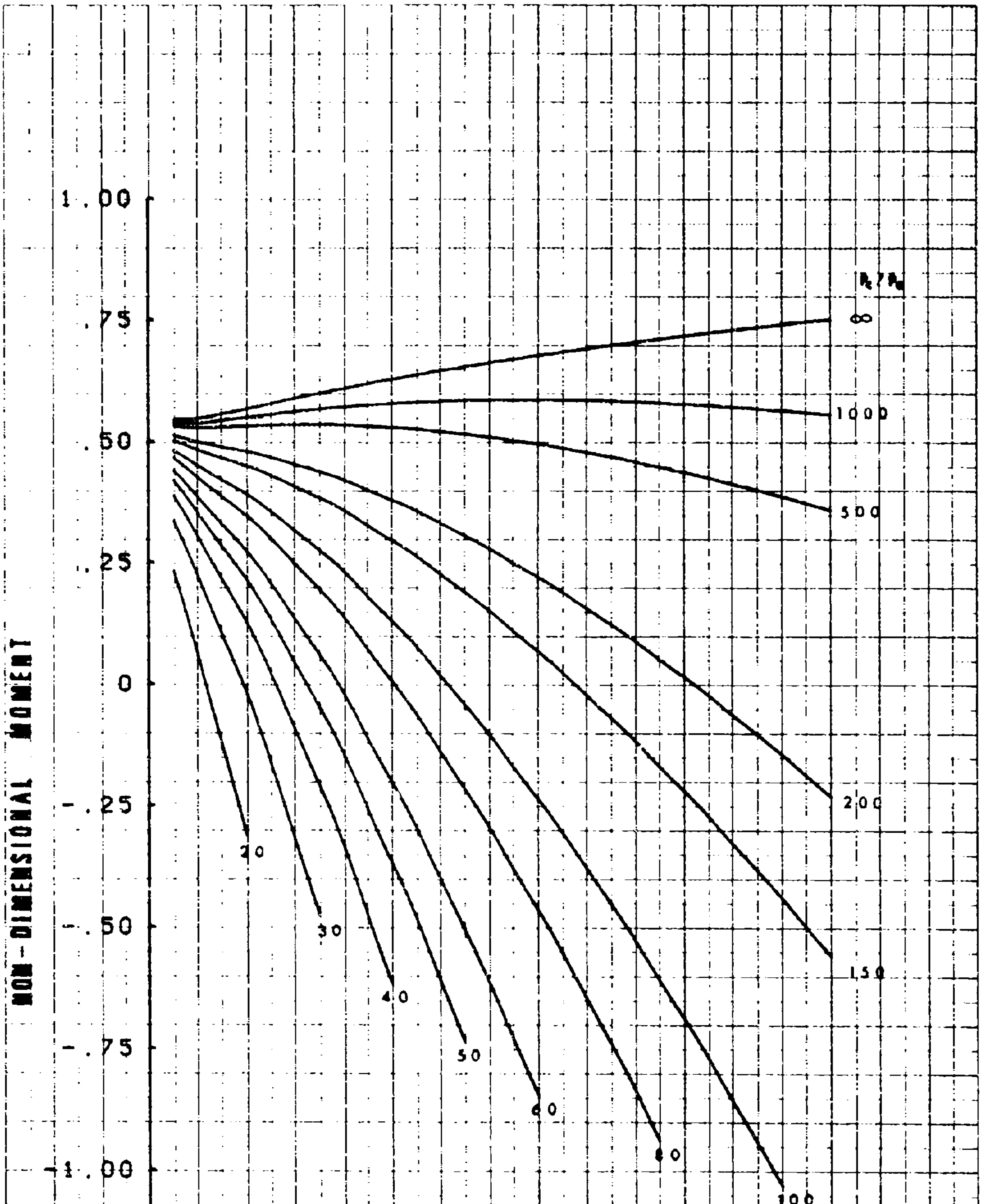
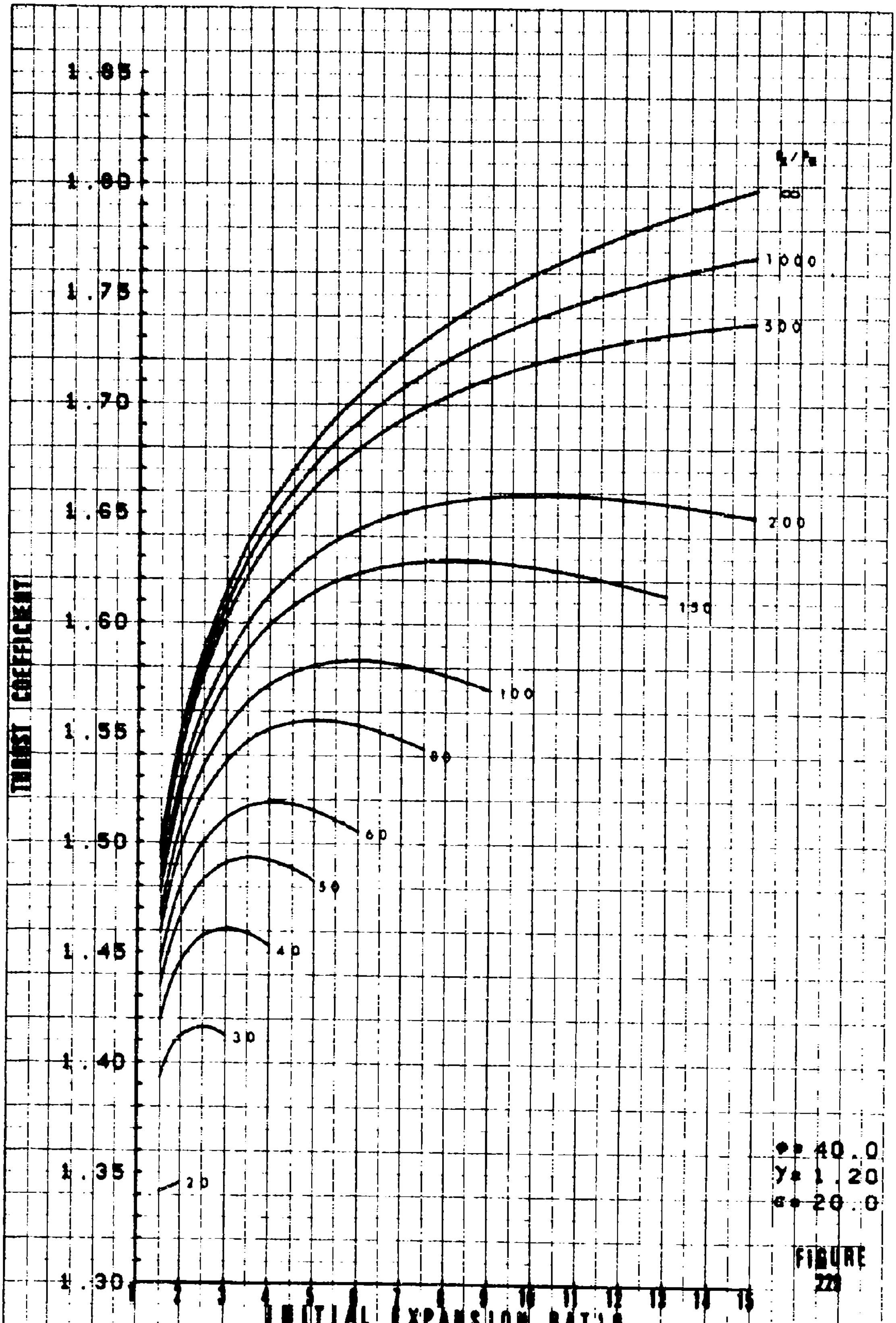

6.0
5.0
4.0
3.0
2.0
1.0
0
-1.0
-2.0
-3.0
THRUST DEFLECTION ANGLE - DEGREES
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
INITIAL EXPANSION RATIO
P_t/P_b
∞
1000
500
200
150
100
80
60
50
40
30
20
φ = 30.0
γ = 1.20
α = 20.0

FIGURE 227



NON-DIMENSIONAL MOMENT
1.00
.75
.50
.25
0
-.25
-.50
-.75
-1.00
-1.25
-1.50
INITIAL EXPANSION RATIO
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
∞
1000
500
200
150
100
80
60
50
40
30
20
FIGURE



THRUST COEFFICIENT
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
P_c/P_a
∞
1000
300
200
150
100
80
60
50
40
30
20
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
INITIAL EXPANSION RATIO
Φ= 40.0
γ= 1.20
ε= 20.0
FIGURE
228

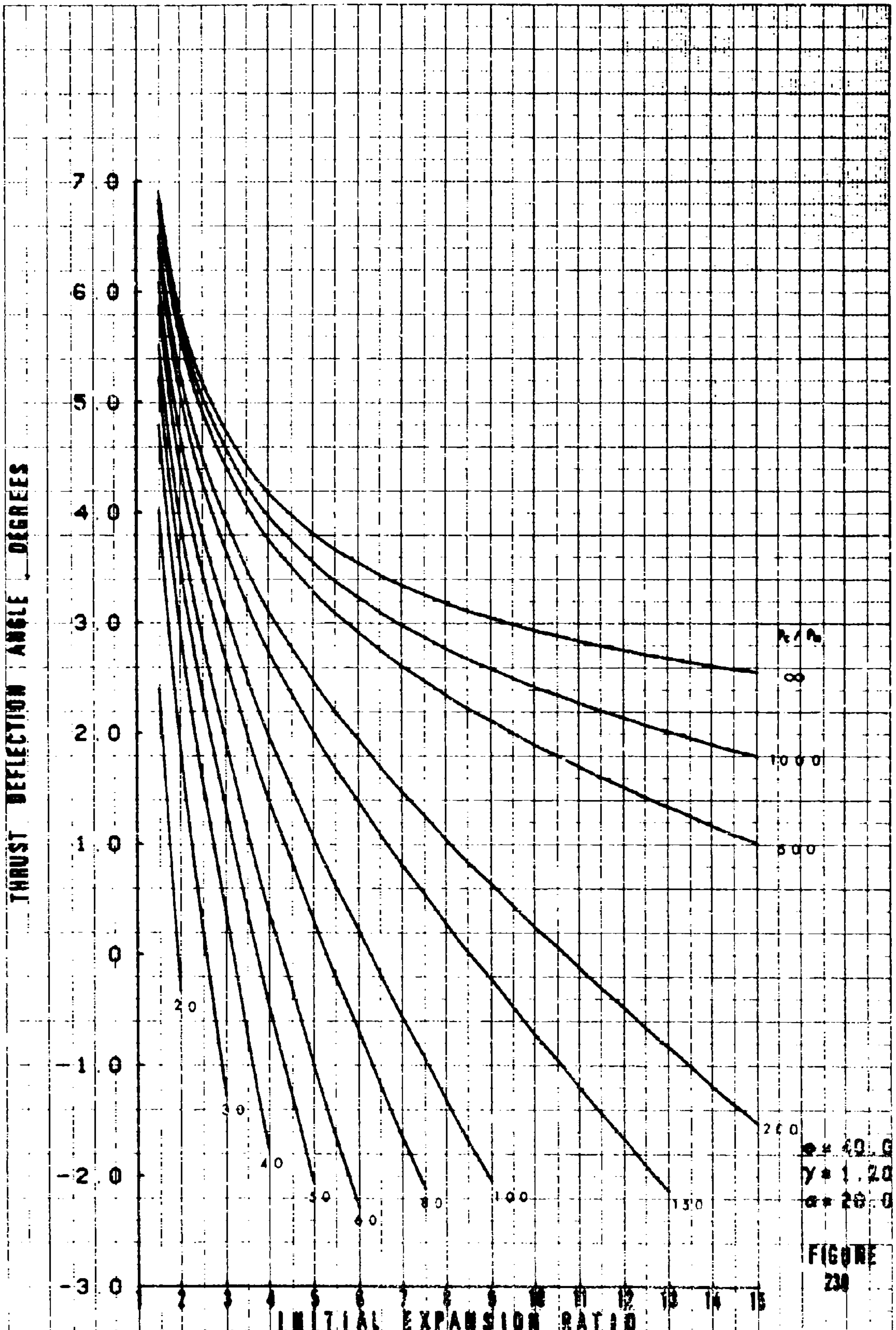
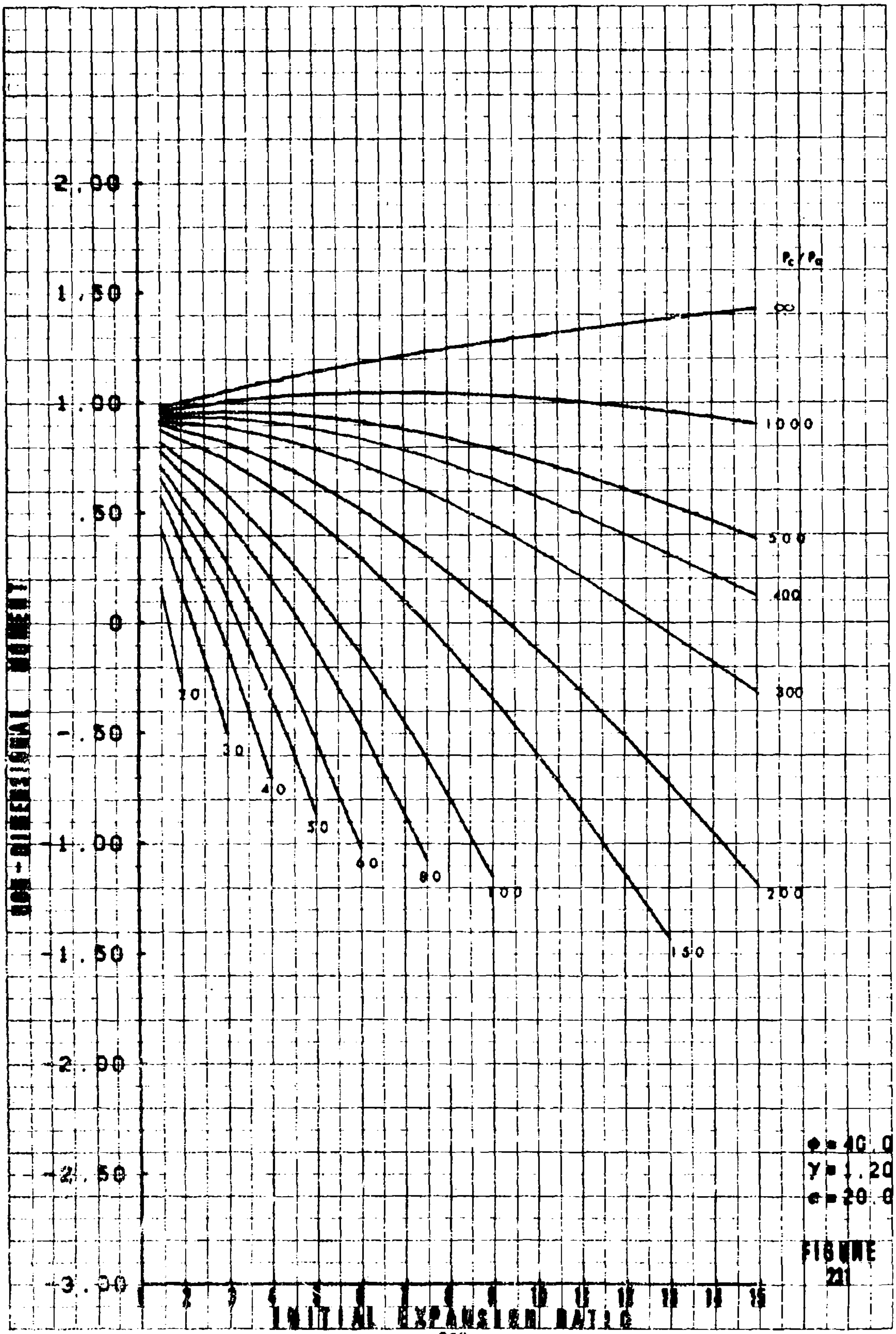
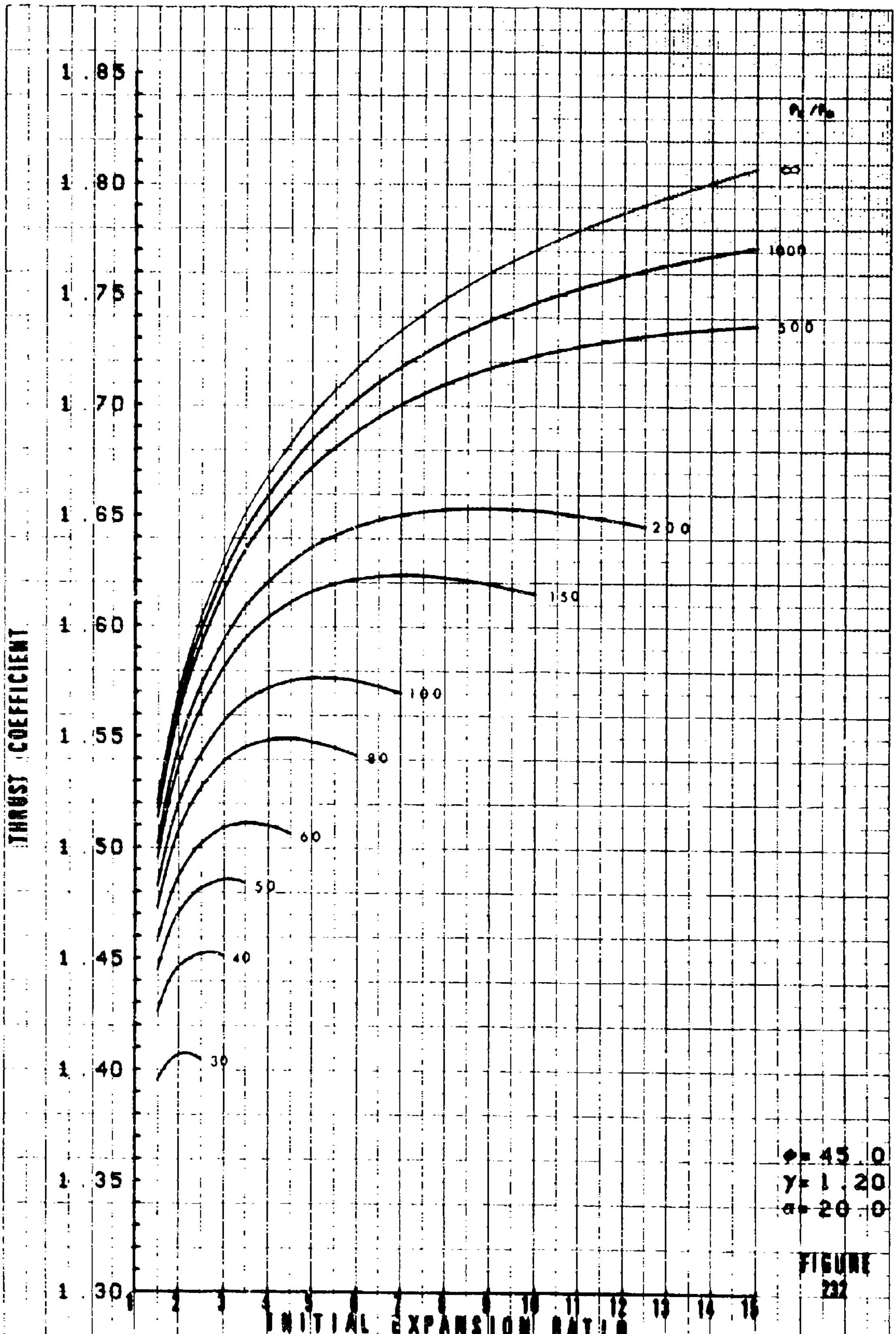

THRUST DEFLECTION ANGLE, DEGREES
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
-1.0
-2.0
-3.0
INITIAL EXPANSION RATIO
P_c/P_a
∞
1000
500
200
150
100
80
60
50
40
30
20
γ = 1.20

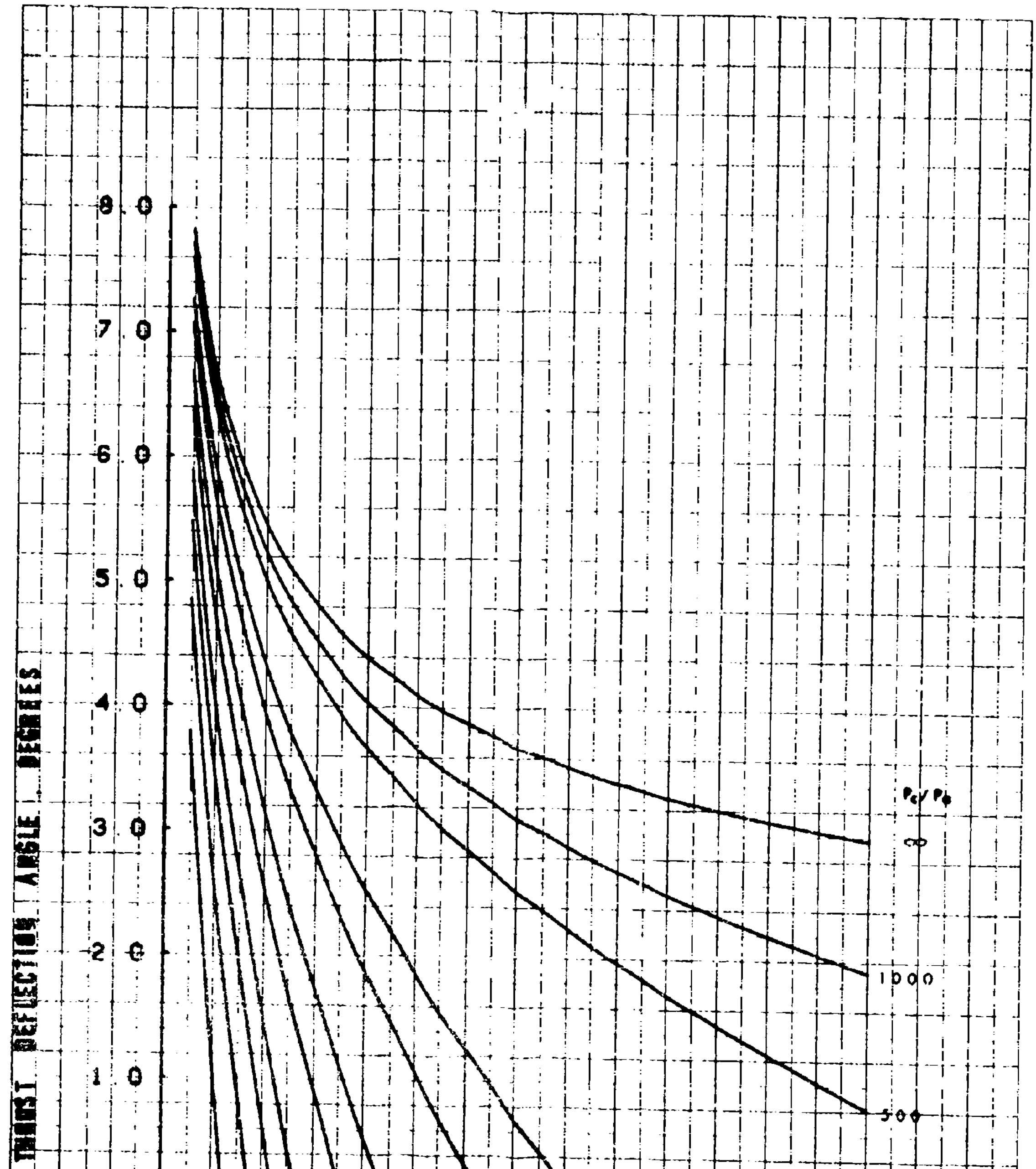
FIGURE 238


NON-DIMENSIONAL MOMENT
INITIAL EXPANSION RATIO
Pc/Pa
∞
1000
500
400
300
200
150
100
80
60
50
40
30
20
2.00
1.50
1.00
.50
0
-.50
-1.00
-1.50
-2.00
-2.50
-3.00
φ = 40.0
γ = 1.20
ε = 20.0
FIGURE
221

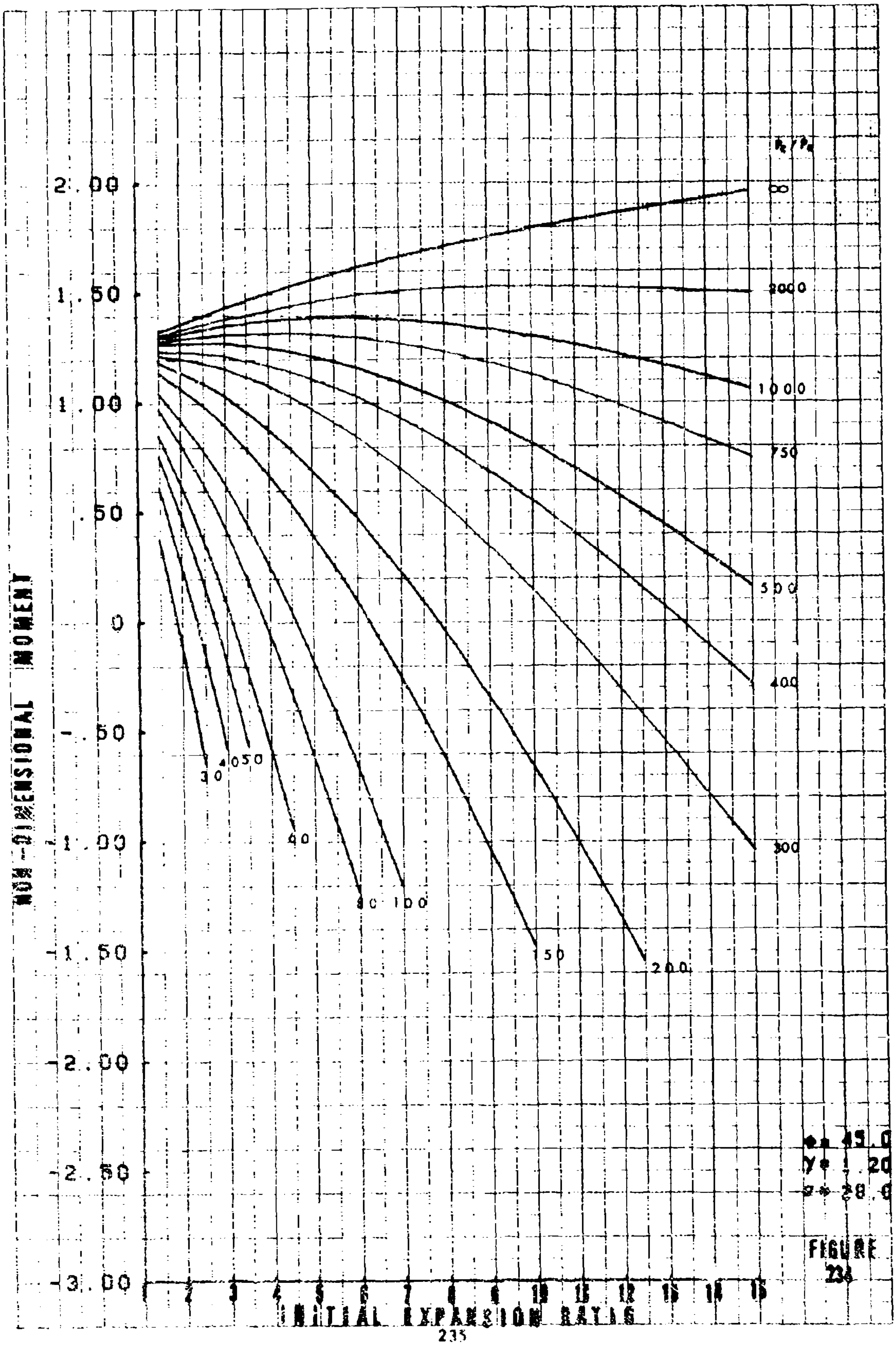


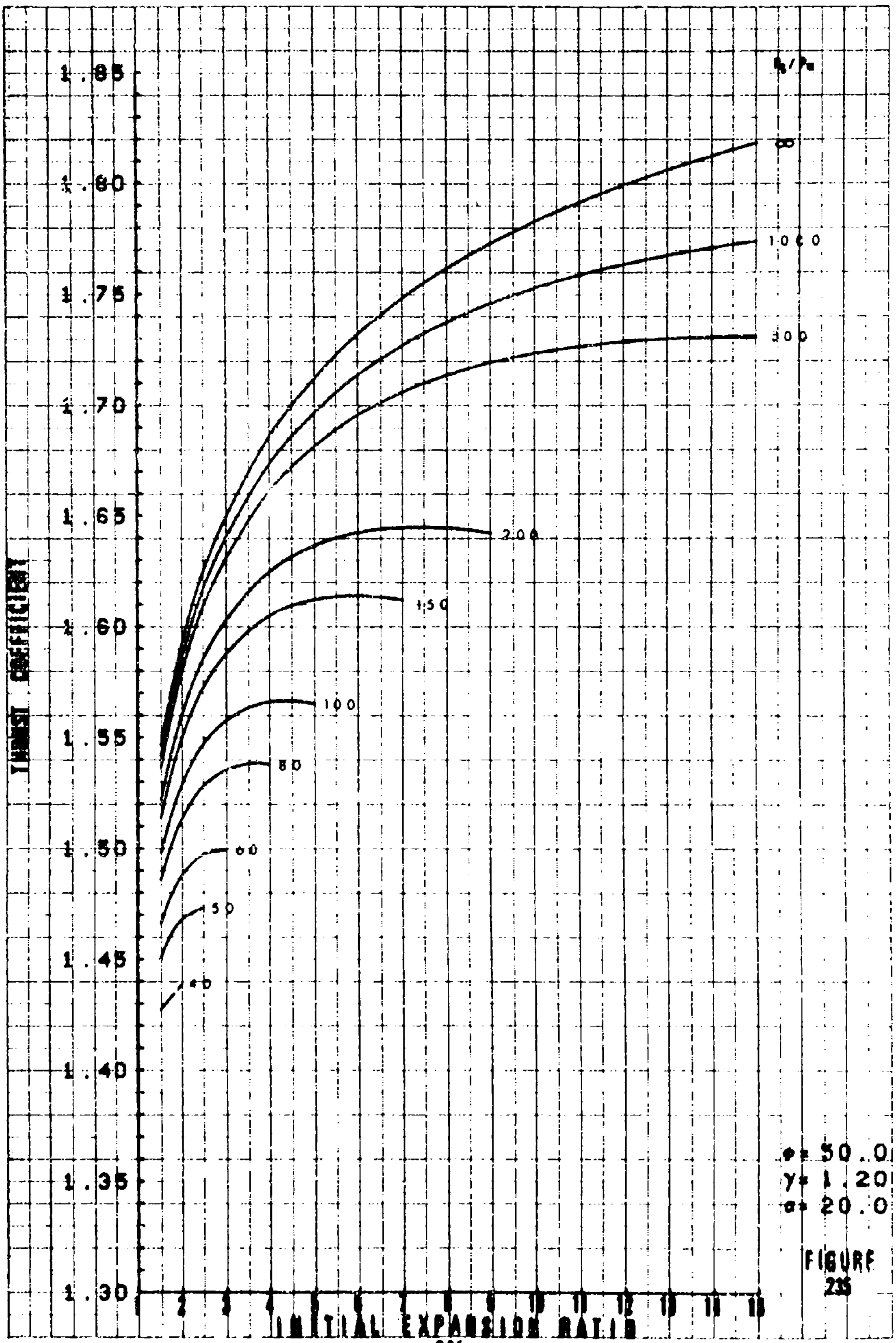
THRUST COEFFICIENT
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
INITIAL EXPANSION RATIO
P_c/P_a
∞
1000
500
200
150
100
80
60
50
40
30
φ = 45.0
γ = 1.20
α = 20.0

FIGURE 232


THRUST DEFLECTION ANGLE DEGREES
INITIAL EXPANSION RATIO
P_c/P_b
∞
1000
500
200
150
100
80
60
50
40
30
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
-1.0
-2.0
φ = 45.0
γ = 1.20
α = 20.0

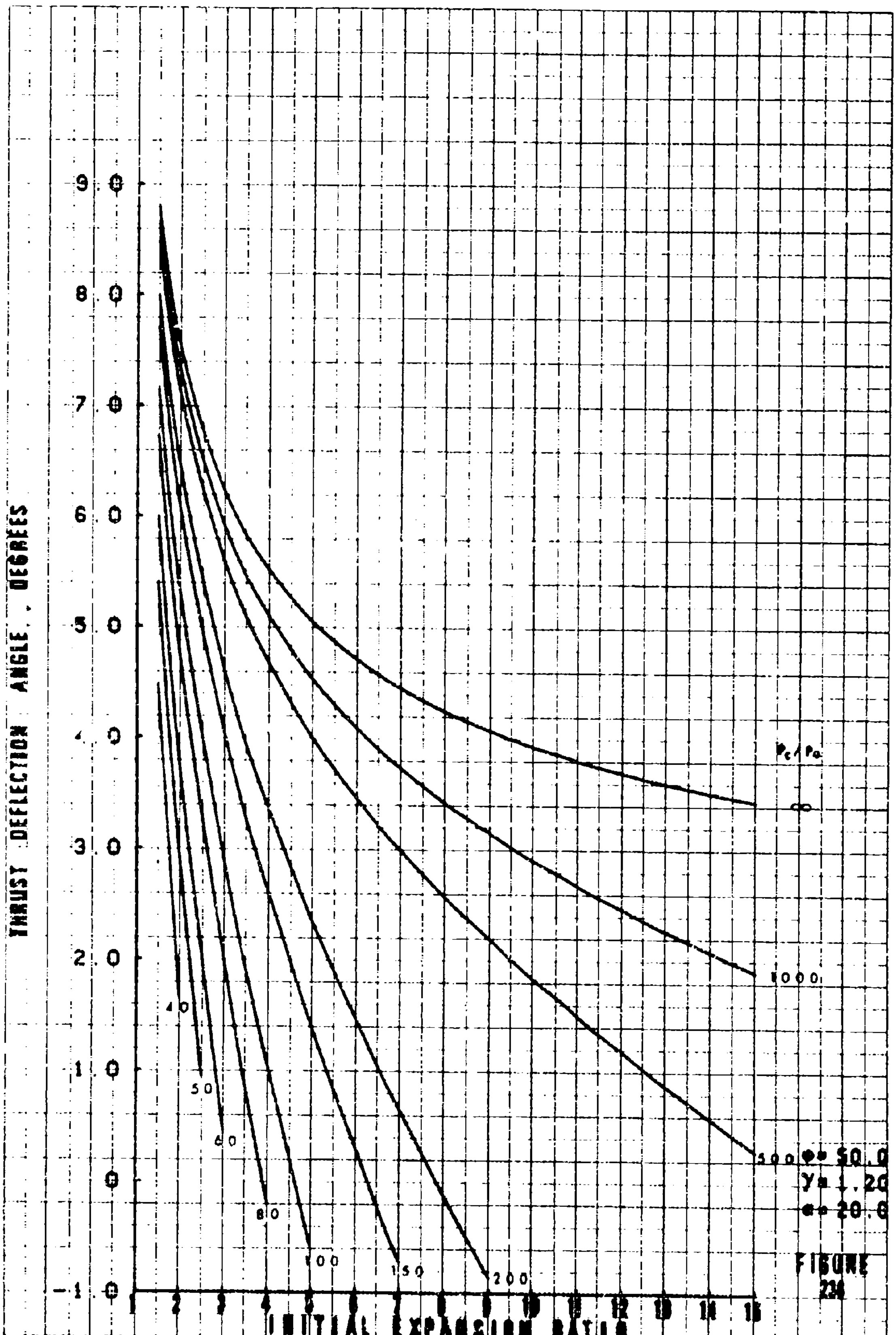
FIGURE


NON-DIMENSIONAL MOMENT
INITIAL EXPANSION RATIO
2.00
1.50
1.00
.50
0
-.50
-1.00
-1.50
-2.00
-2.50
-3.00
∞
2000
1000
750
500
400
300
200
150
100
80
60
50
40
30
FIGURE 234



1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
THRUST COEFFICIENT
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
INITIAL EXPANSION RATIO
∞
1000
300
200
150
100
80
60
50
40
φ= 50.0
γ= 1.20
α= 20.0

FIGURE 235


THRUST DEFLECTION ANGLE, DEGREES
INITIAL EXPANSION RATIO
P_c/P_a
∞
1000
500
200
150
100
80
60
50
40
ϕ= 50.0
γ= 1.20
α= 20.0
FIGURE
236

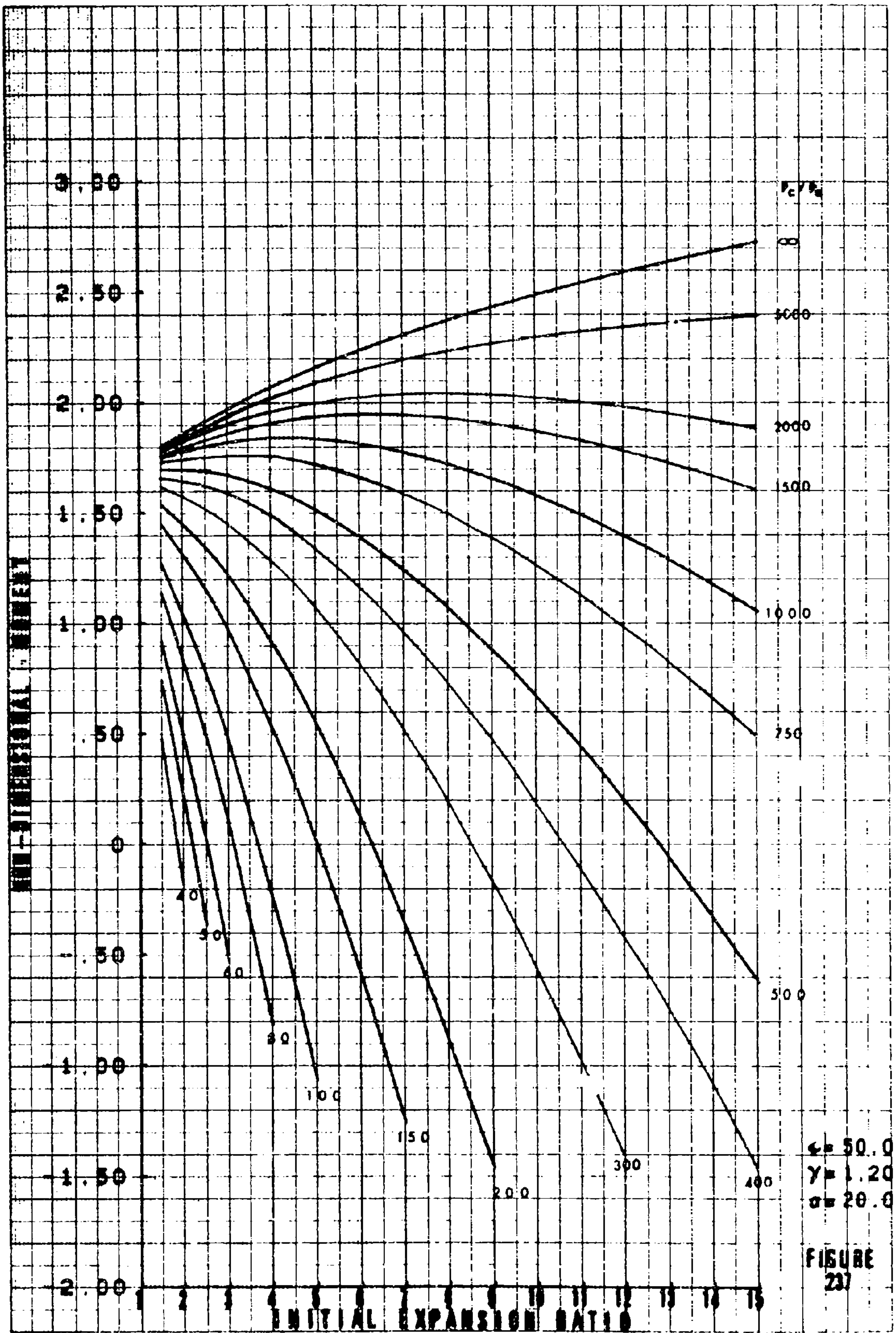
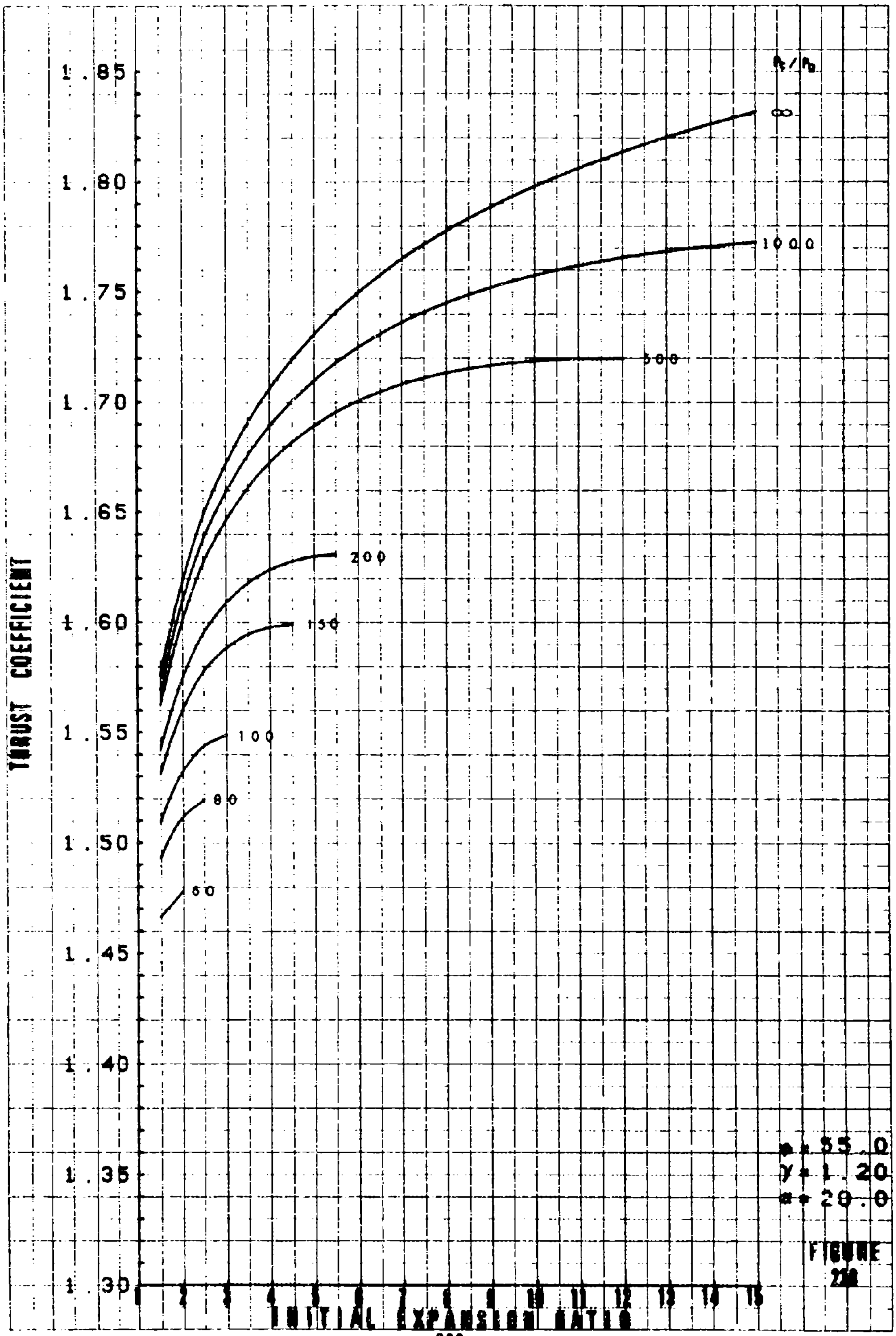

NON-DIMENSIONAL MOMENT
3.00
2.50
2.00
1.50
1.00
.50
0
-.50
-1.00
-1.50
-2.00
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
INITIAL EXPANSION RATIO
P_c/P_e
∞
3000
2000
1500
1000
750
500
400
300
200
150
100
80
60
50
40
ε= 50.0
γ= 1.20
α= 20.0

FIGURE 237



THRUST COEFFICIENT
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
INITIAL EXPANSION RATIO
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
∞
1000
500
200
150
100
80
60
55.0
γ = 1.20
20.0
FIGURE

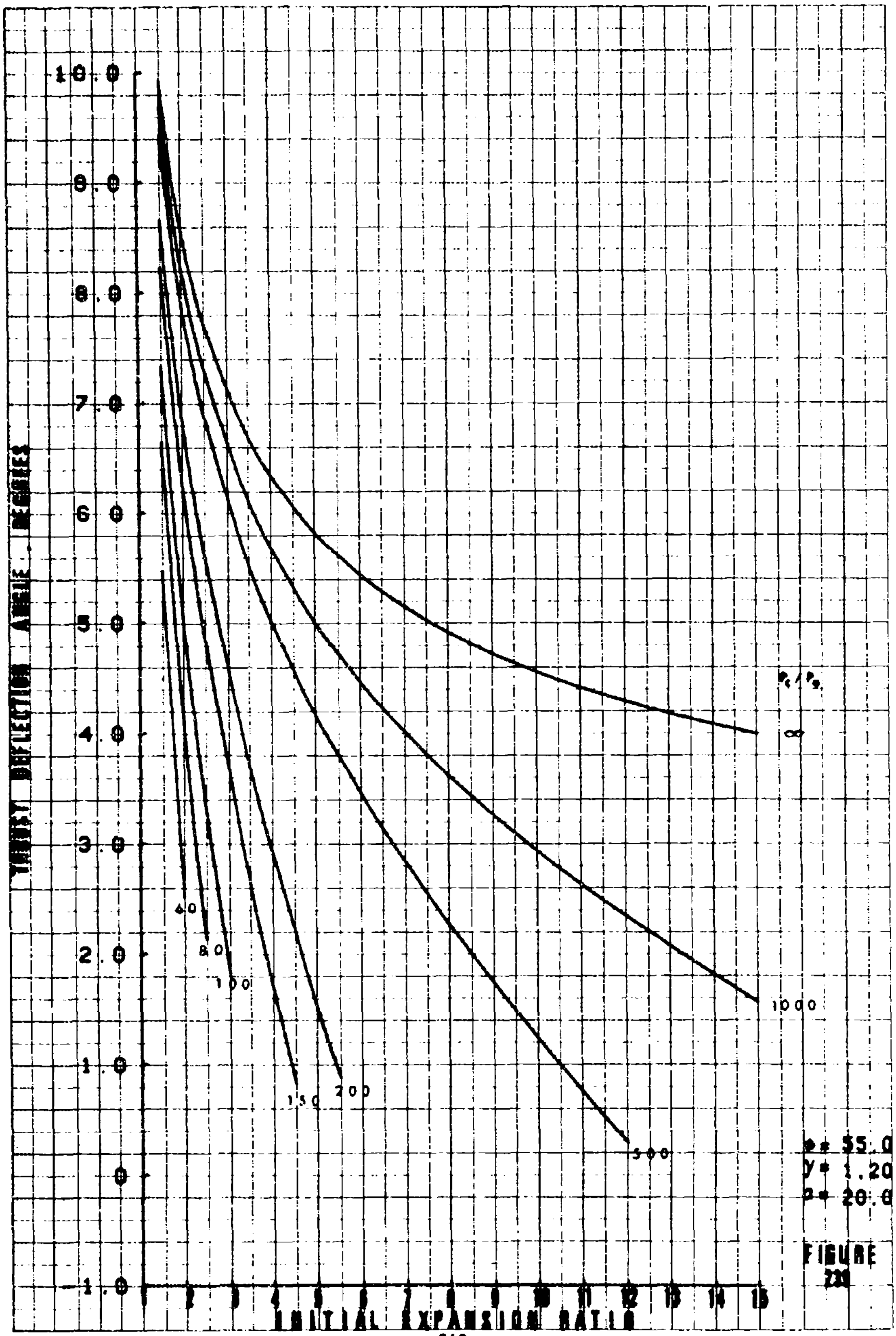
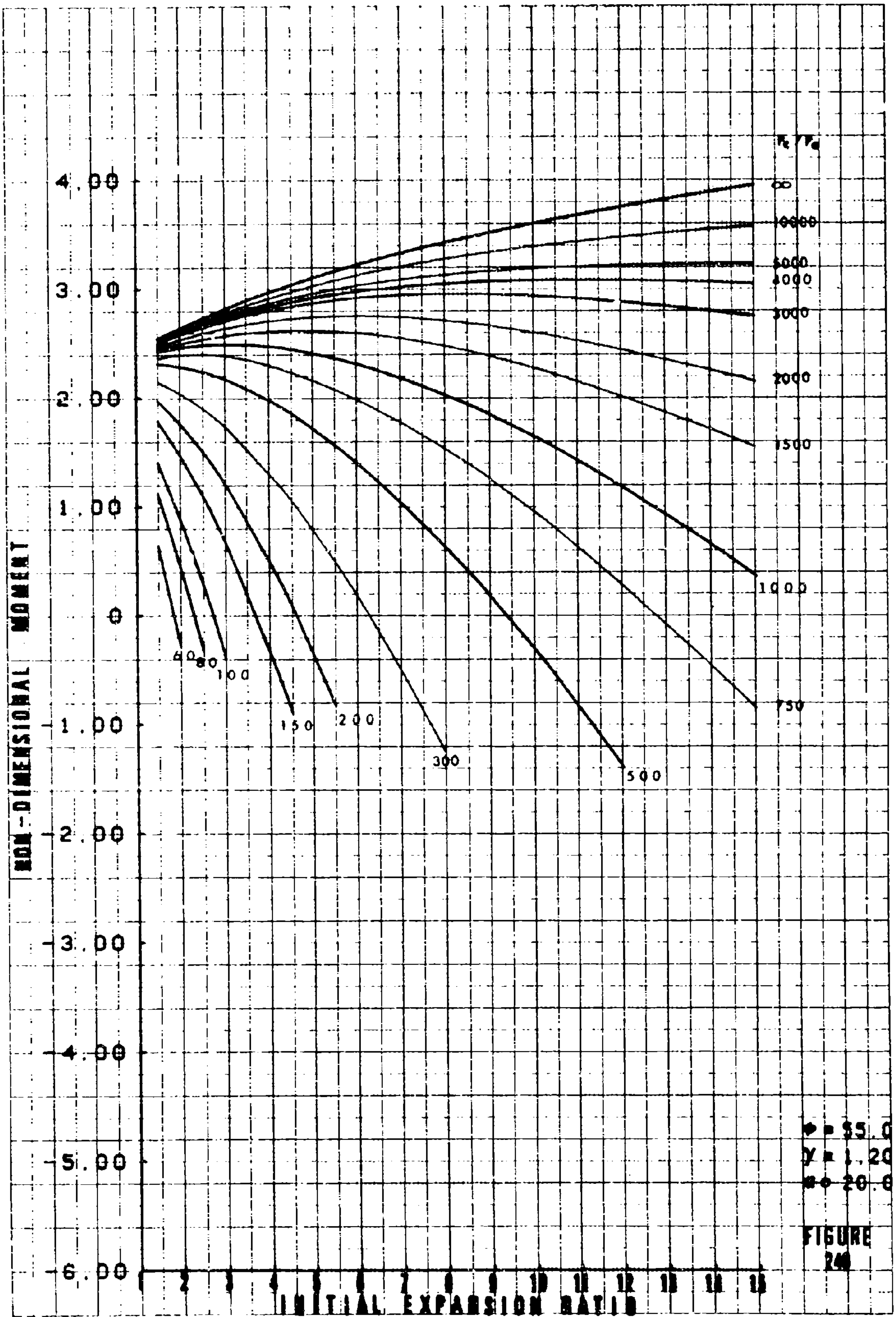
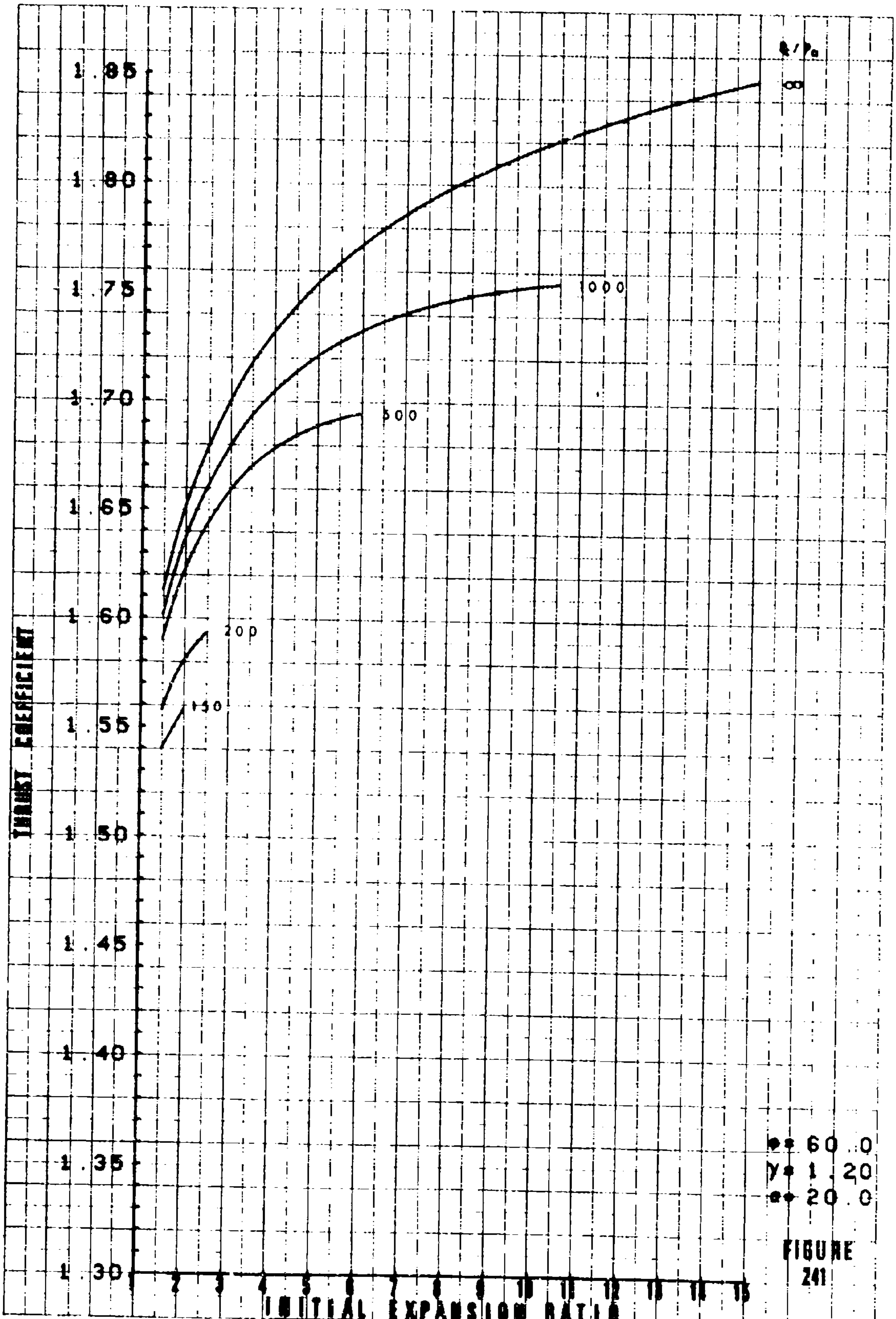

THRUST DEFLECTION ANGLE DEGREES
INITIAL EXPANSION RATIO
P_c/P_a
∞
1000
500
200
150
100
80
60
Φ= 55.0
γ= 1.20
α= 20.0

FIGURE 73



ϕ = 55.0
γ = 1.20
θ_0 = 20.0

FIGURE 240



THRUST COEFFICIENT
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
INITIAL EXPANSION RATIO
2
3
4
5
6
7
8
9
10
11
12
13
14
15
P_c/P_a
∞
1000
500
200
150
θ = 60.0
γ = 1.20
α = 20.0

FIGURE 241

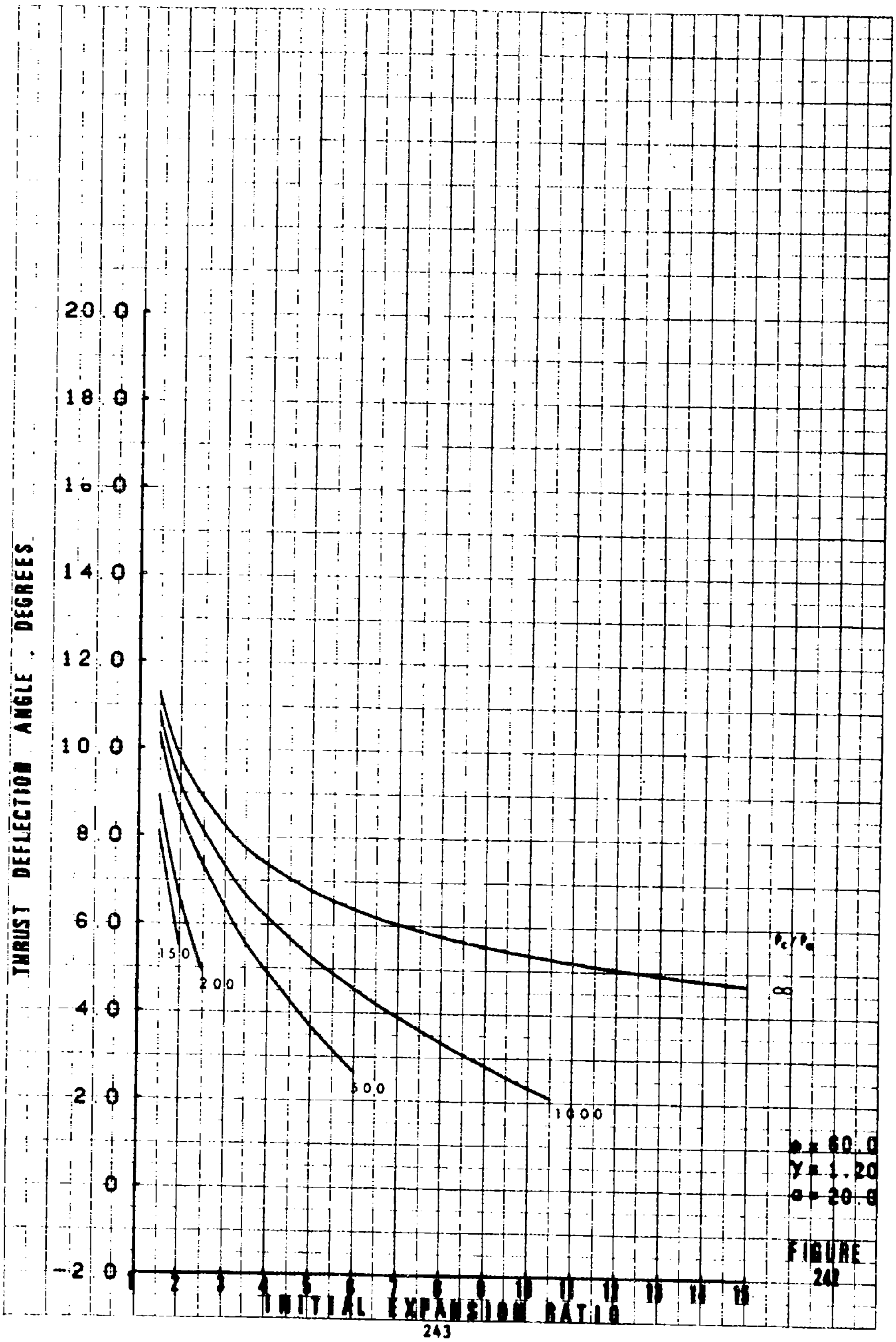
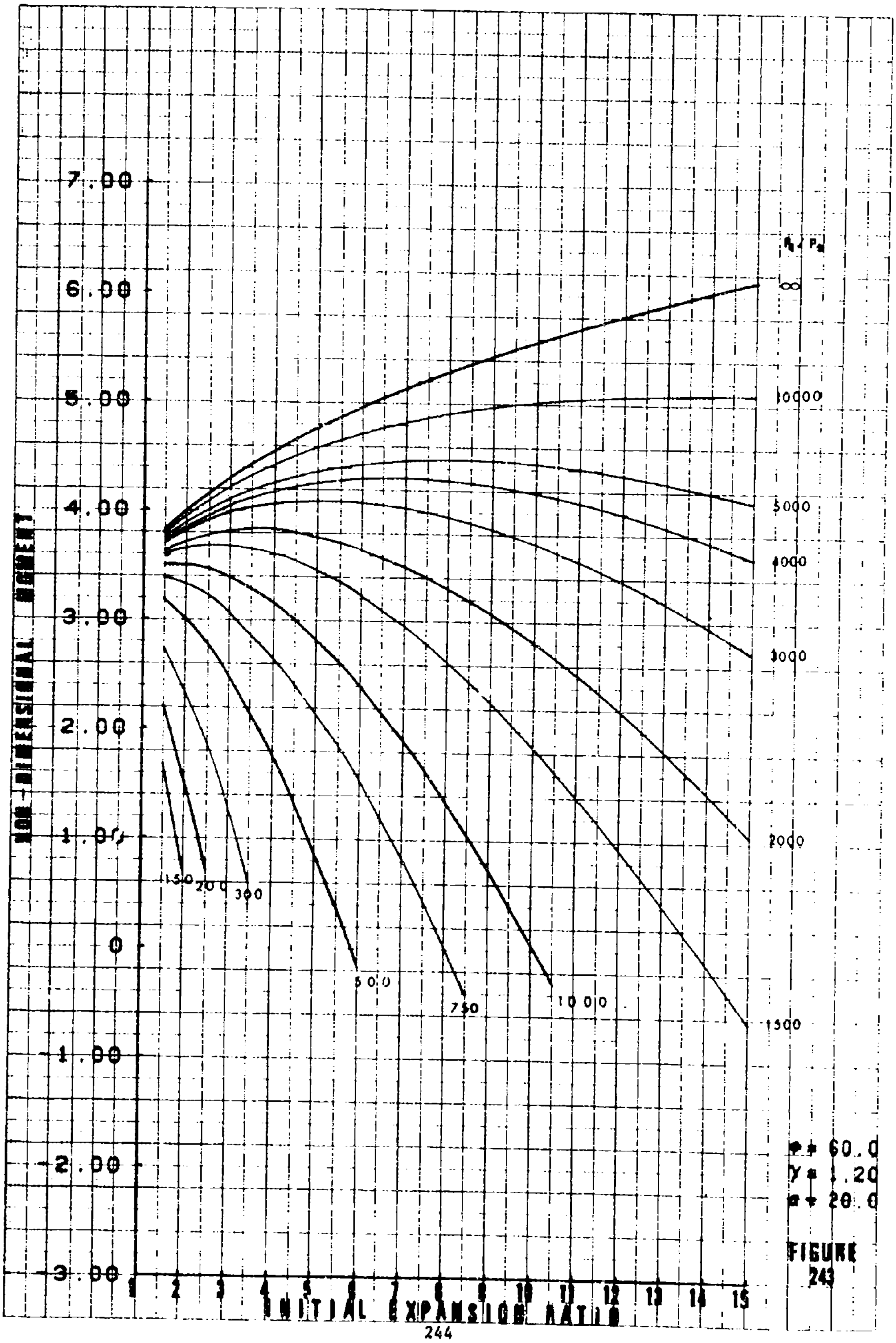
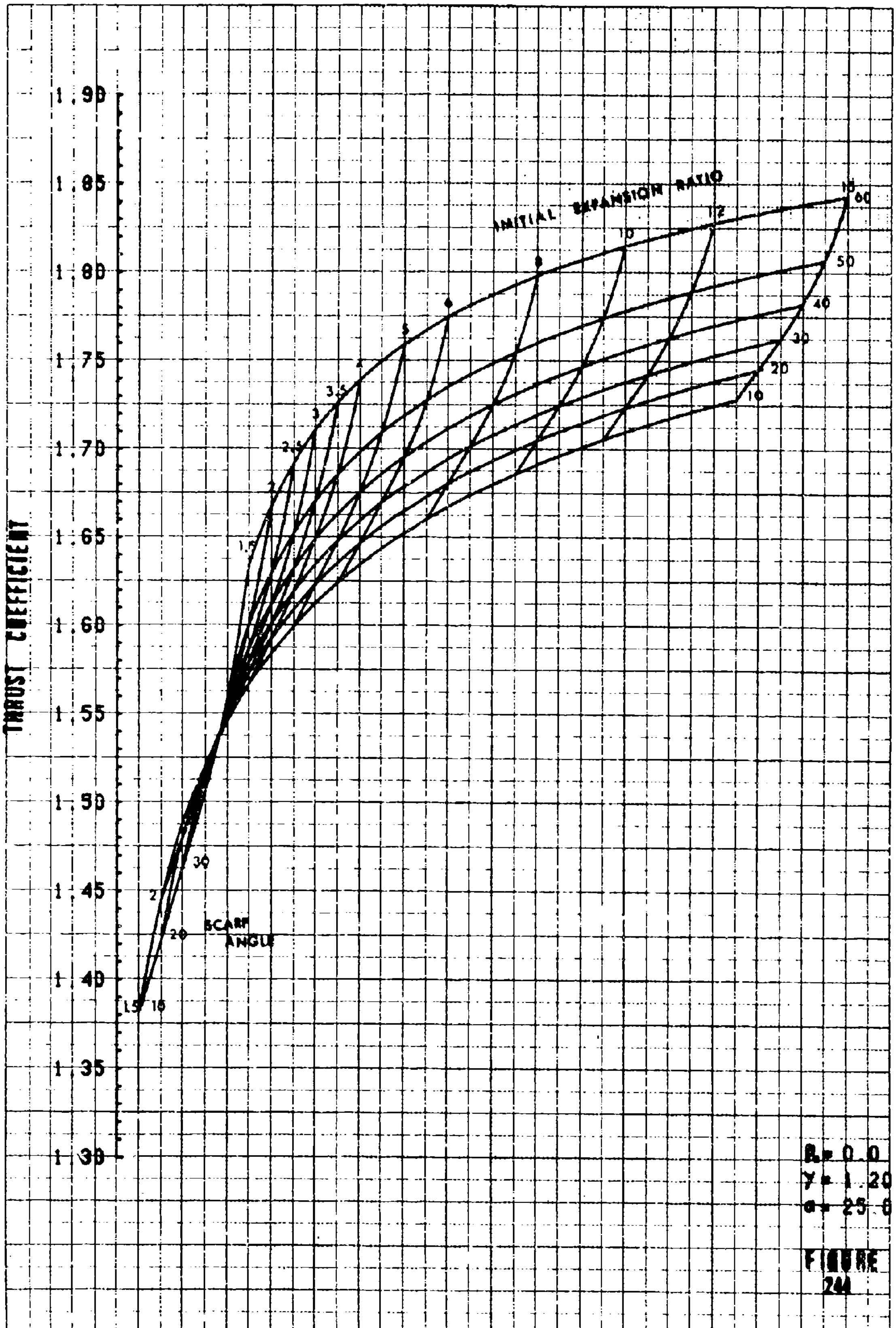

THRUST DEFLECTION ANGLE, DEGREES
20.0
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0
-2.0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
INITIAL EXPANSION RATIO
150
200
500
1000
P_c/P_a
∞
γ = 1.20

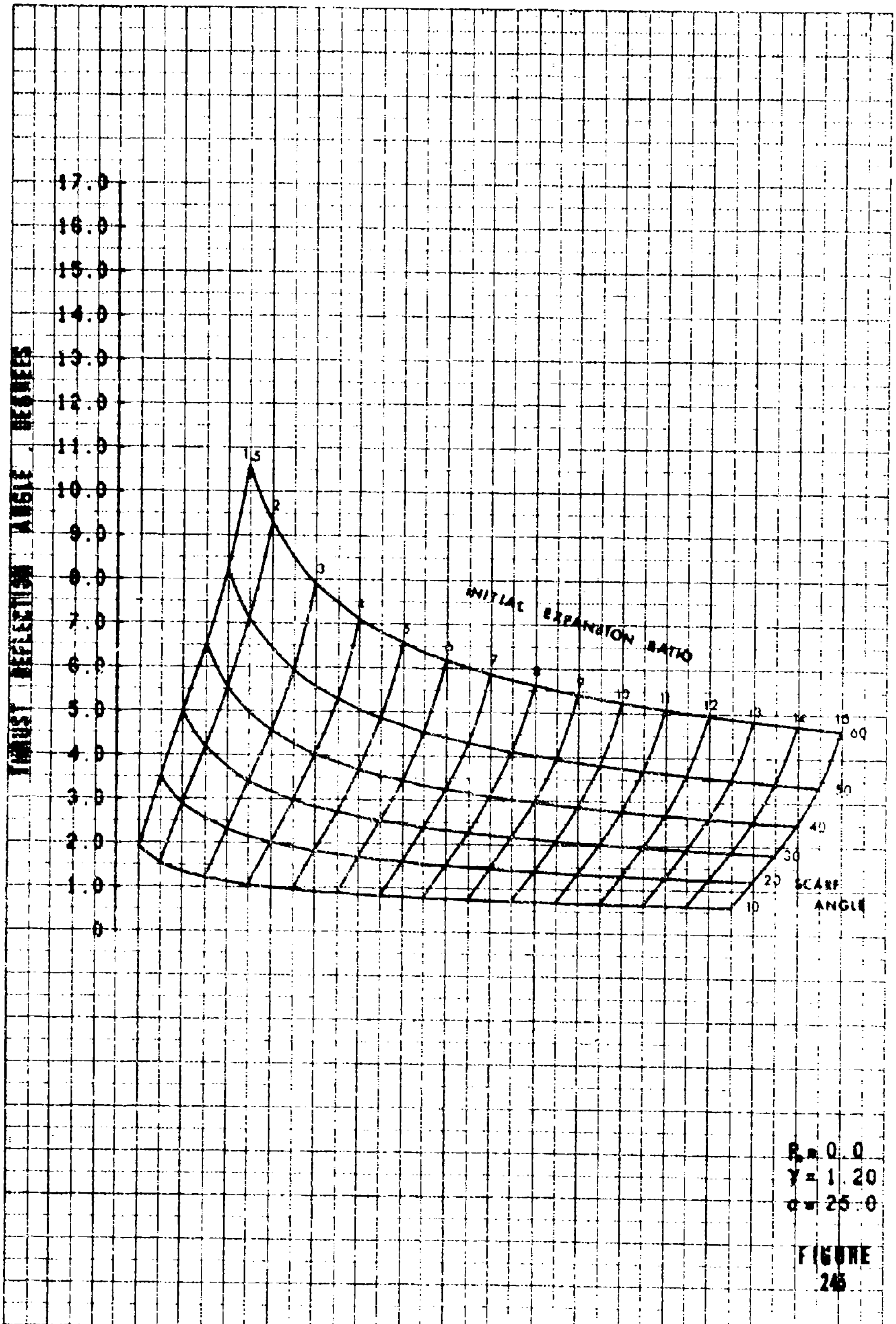
FIGURE 242



7.00
6.00
5.00
4.00
3.00
2.00
1.00
0
-1.00
-2.00
-3.00
NON-DIMENSIONAL MOMENT
INITIAL EXPANSION RATIO
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
∞
10000
5000
4000
3000
2000
1500
1000
750
500
300
200
150

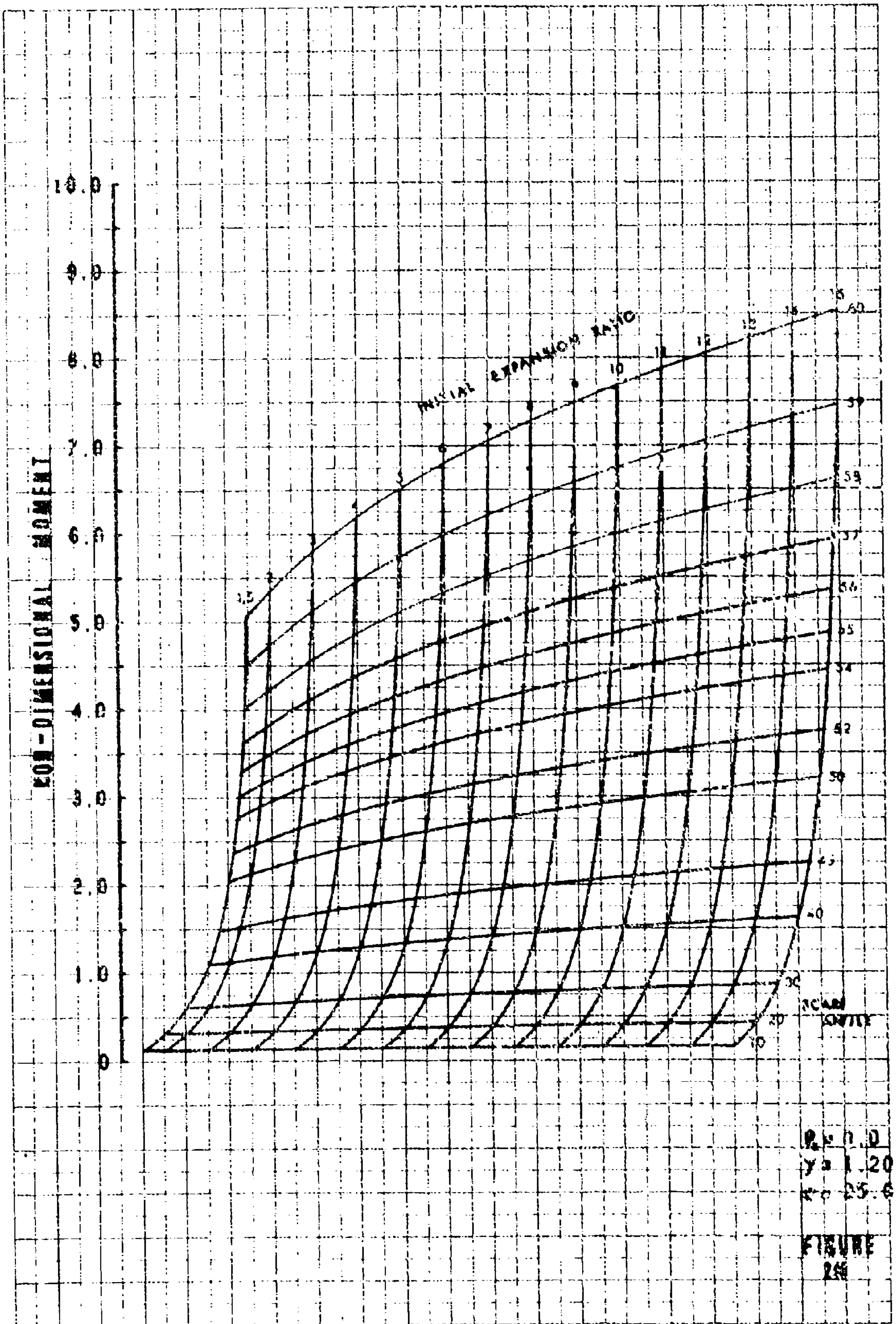
FIGURE 243


THRUST COEFFICIENT
1.90
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
INITIAL EXPANSION RATIO
SCARF ANGLE

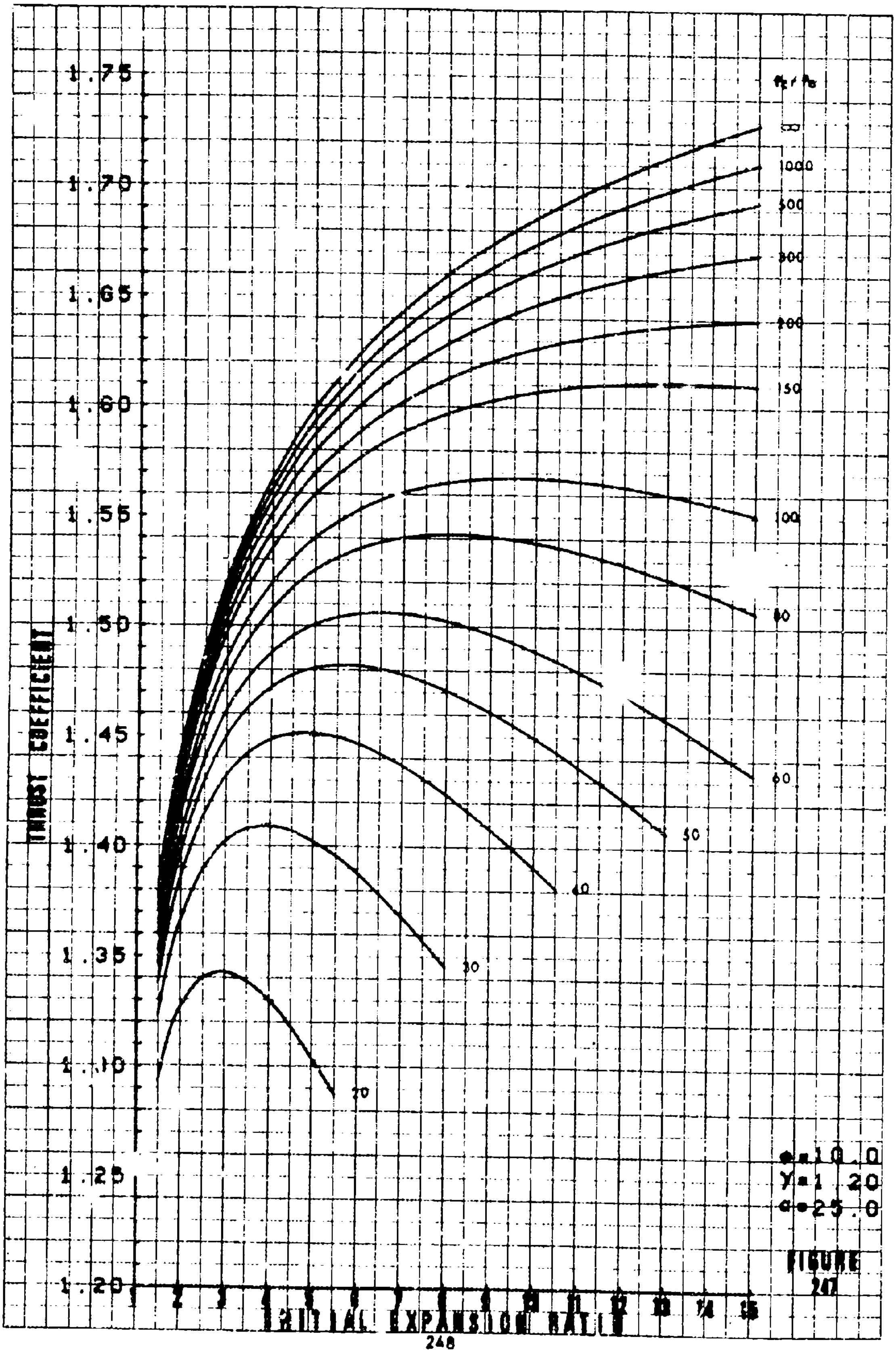


$P_a = 0.0$
$\gamma = 1.20$
$\alpha = 25.0$

FIGURE 245


NON-DIMENSIONAL MOMENT
INITIAL EXPANSION RATIO
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
γ = 1.20

FIGURE


THRUST COEFFICIENT
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
1.25
1.20
P_c/P_a
∞
1000
500
300
200
150
100
80
60
50
40
30
20
ε=10.0
γ=1.20
α=25.0
FIGURE 247
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO

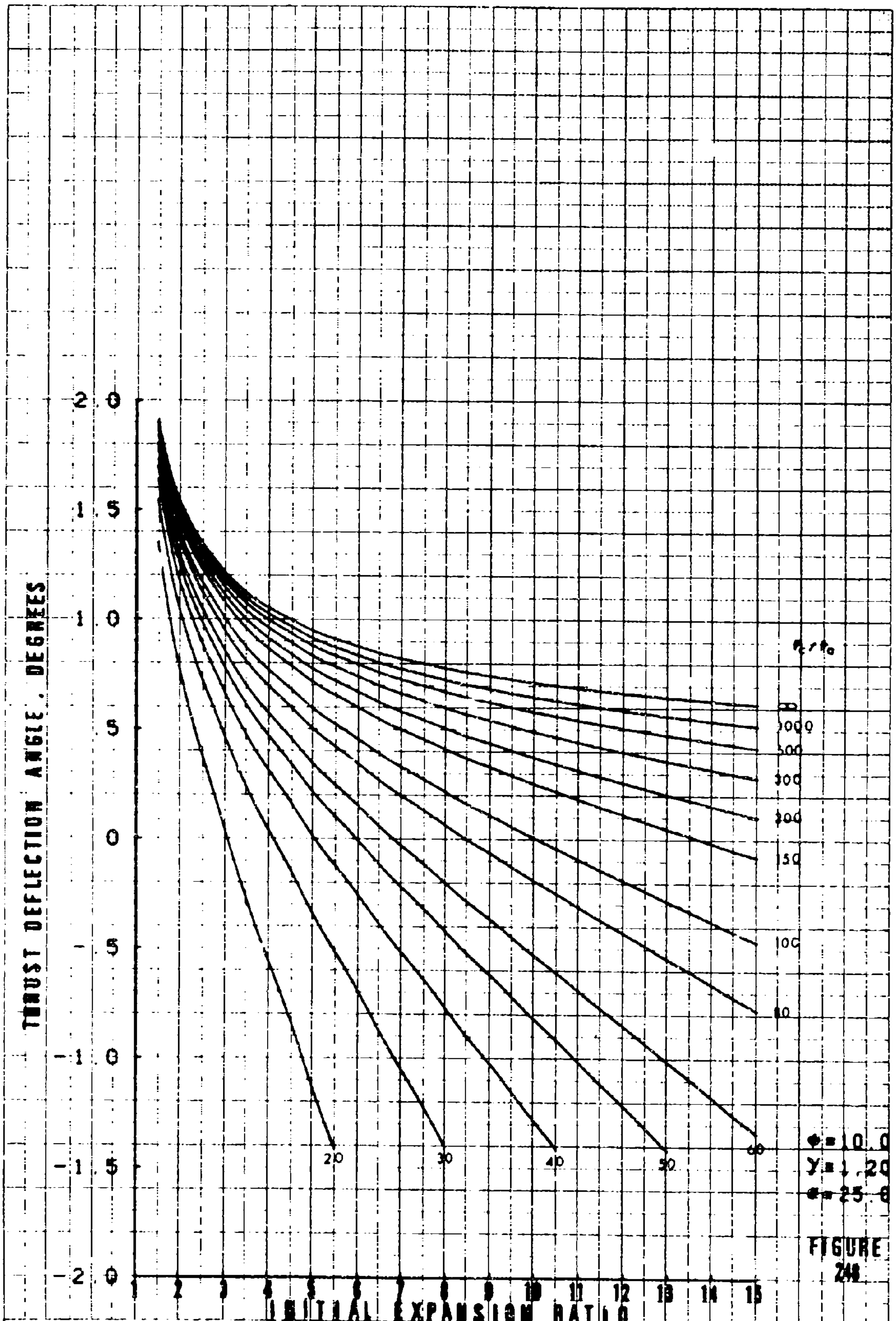
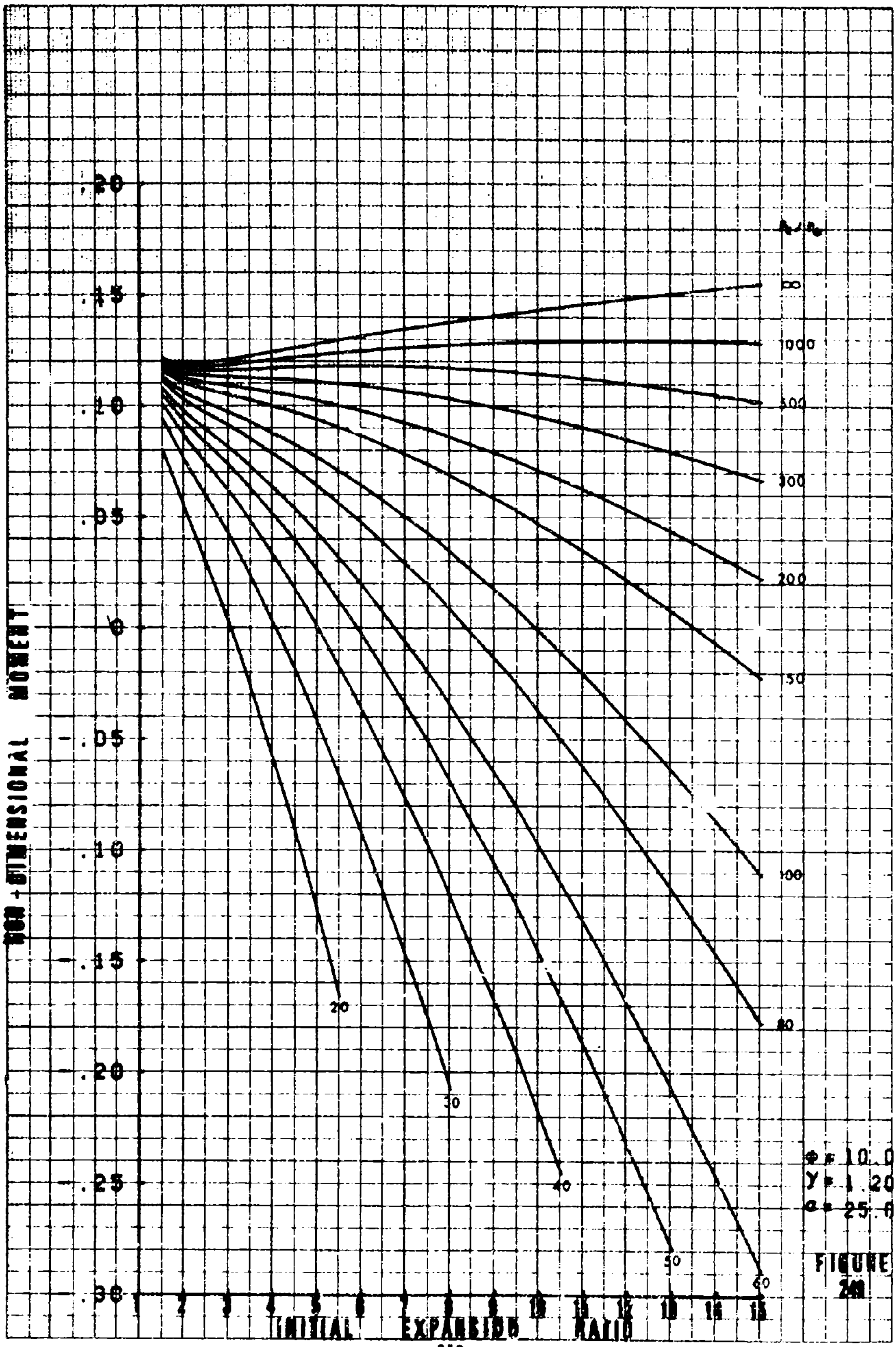

THRUST DEFLECTION ANGLE, DEGREES
2.0
1.5
1.0
.5
0
-.5
-1.0
-1.5
-2.0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
INITIAL EXPANSION RATIO
20
30
40
50
60
80
100
150
200
300
500
1000

FIGURE
248


NON-DIMENSIONAL MOMENT
.20
.15
.10
.05
0
-.05
-.10
-.15
-.20
-.25
-.30
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
INITIAL EXPANSION RATIO
∞
1000
500
300
200
150
100
80
20
30
40
50
60
FIGURE

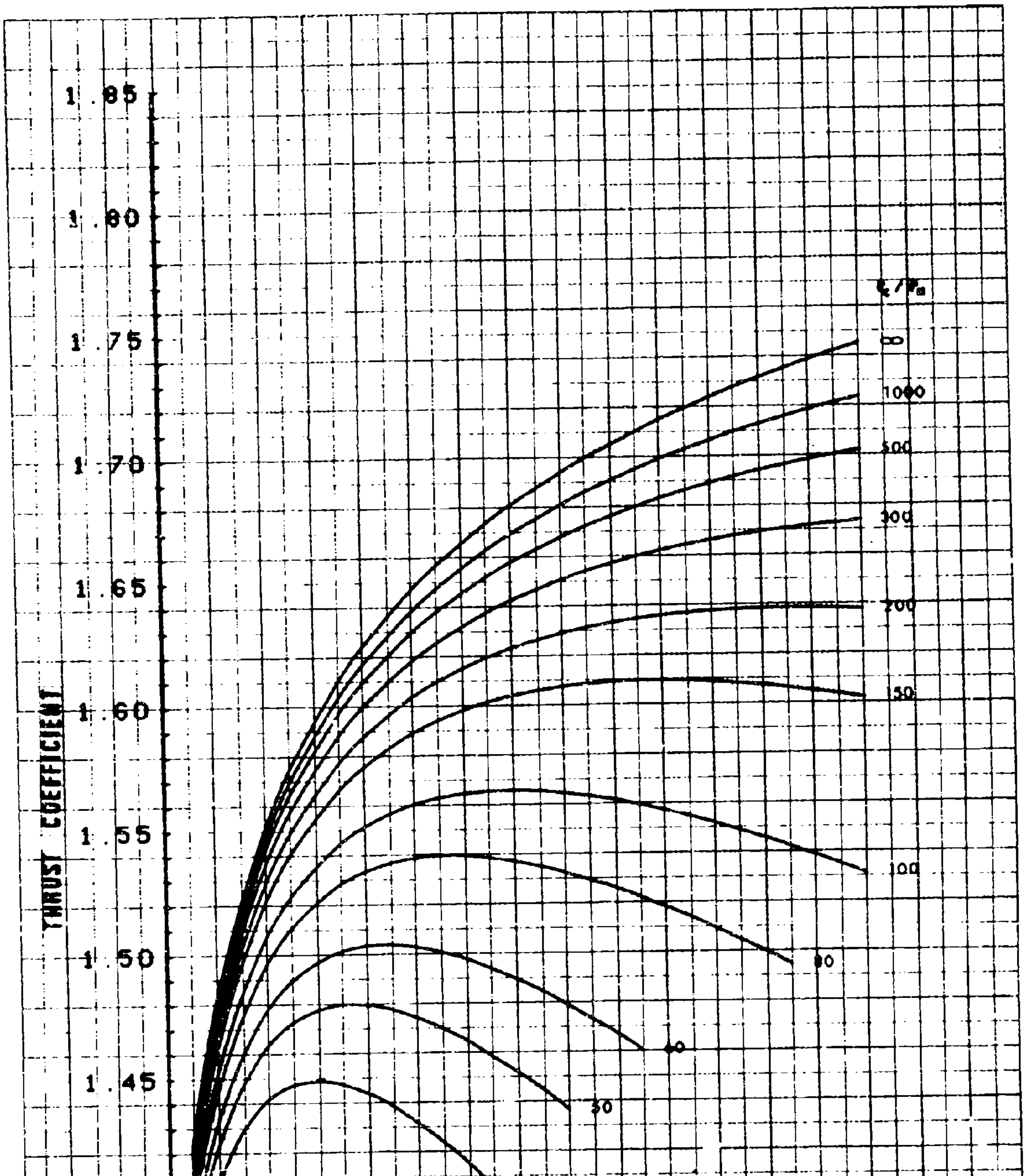
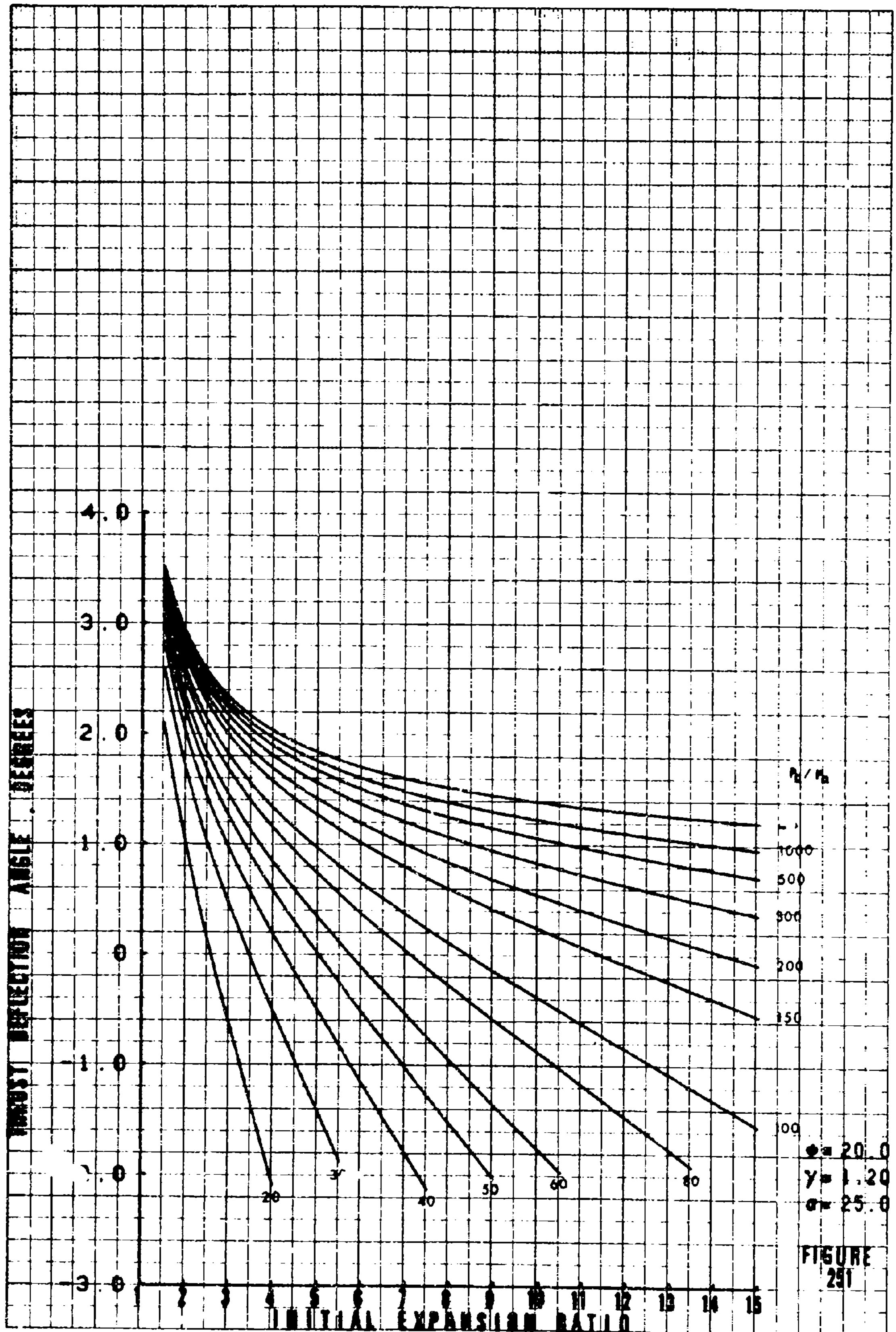

THRUST COEFFICIENT
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
INITIAL EXPANSION RATIO
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
∞
1000
500
300
200
150
100
80
60
50
40
30
20
φ=20.0
γ=1.20
α=15.0

FIGURE 250



4.0
3.0
2.0
1.0
0
-1.0
-2.0
-3.0
THRUST DEFLECTION ANGLE, DEGREES
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
1000
500
300
200
150
100
20
30
40
50
60
80
φ= 20.0
γ= 1.20
σ= 25.0
FIGURE 251

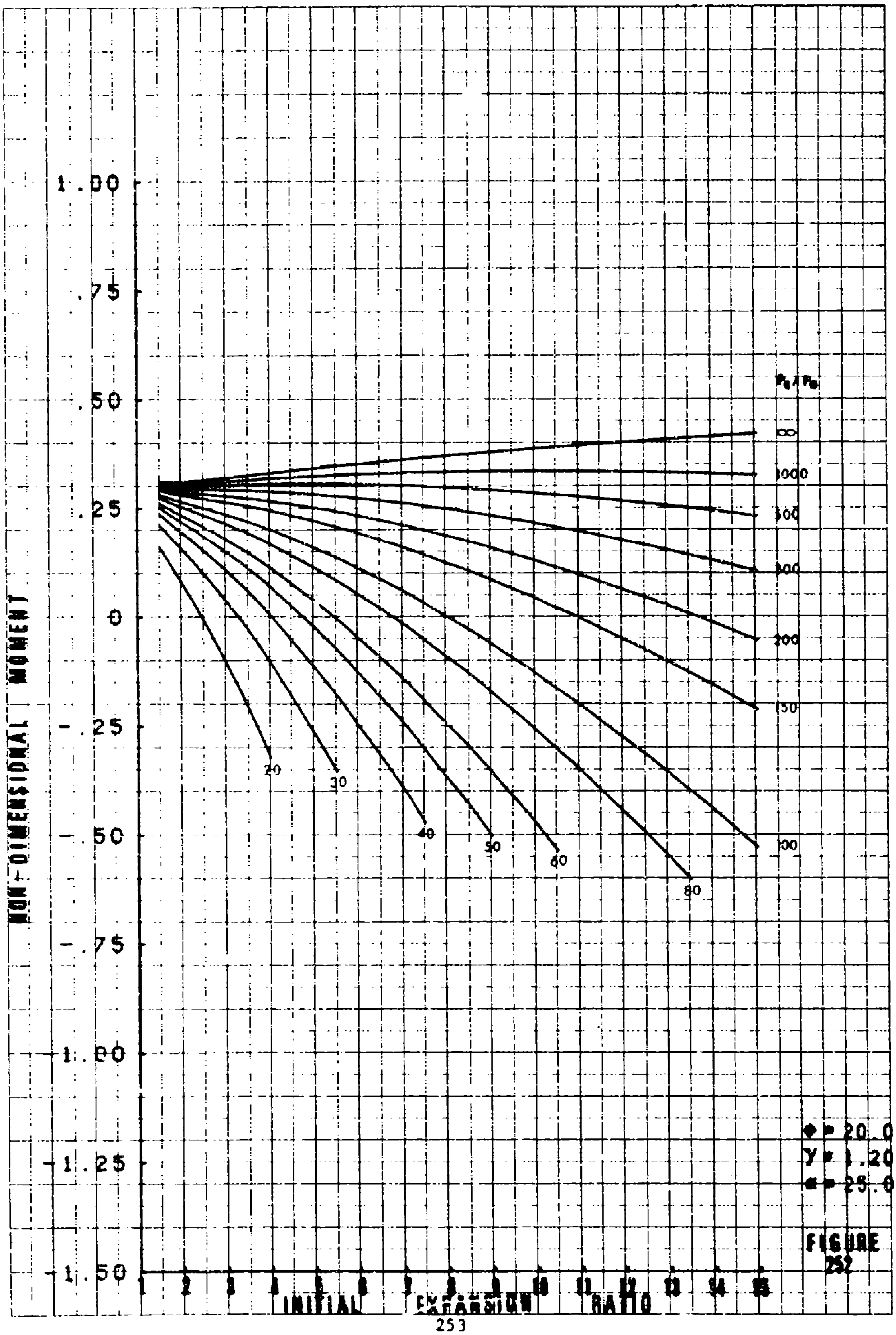
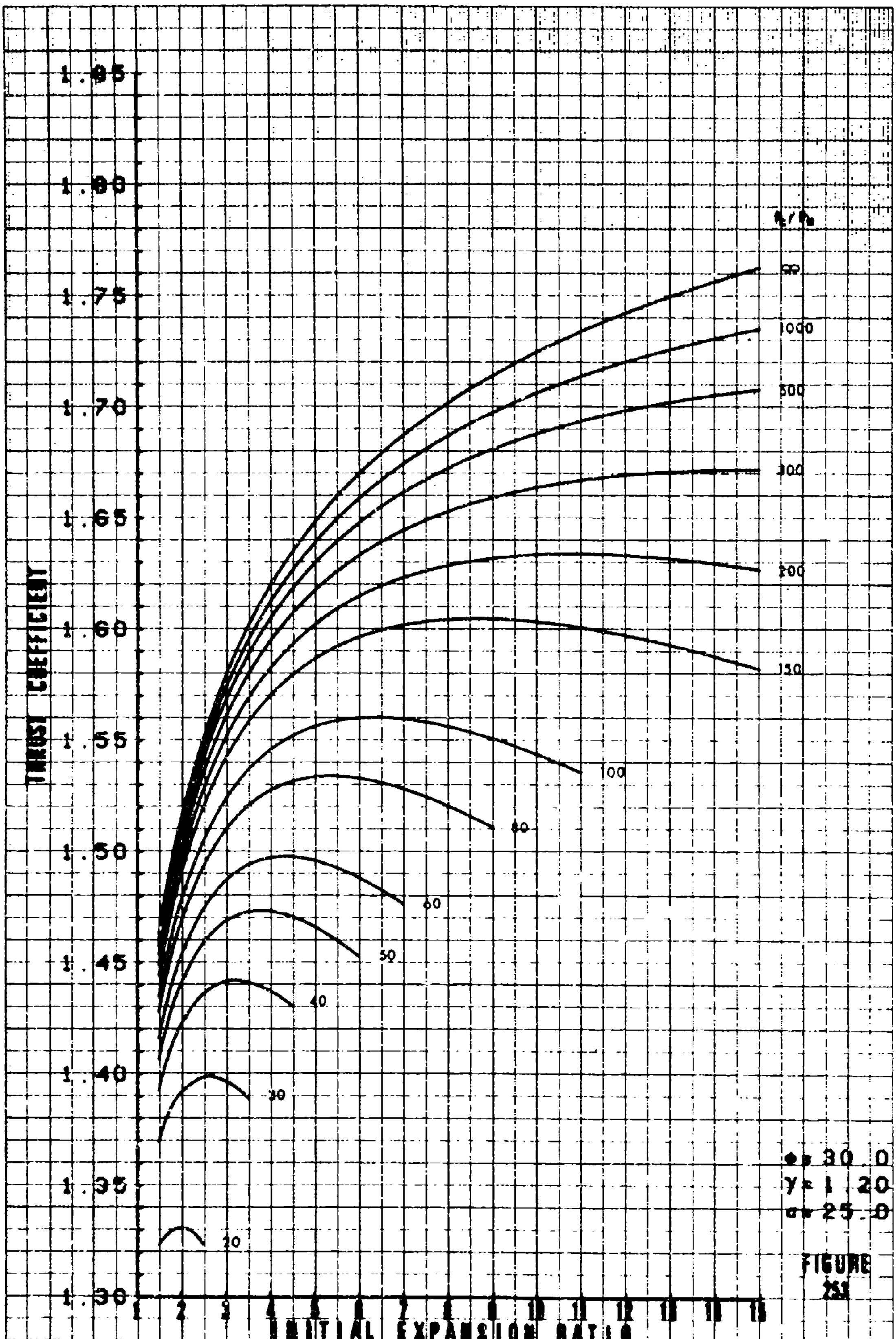
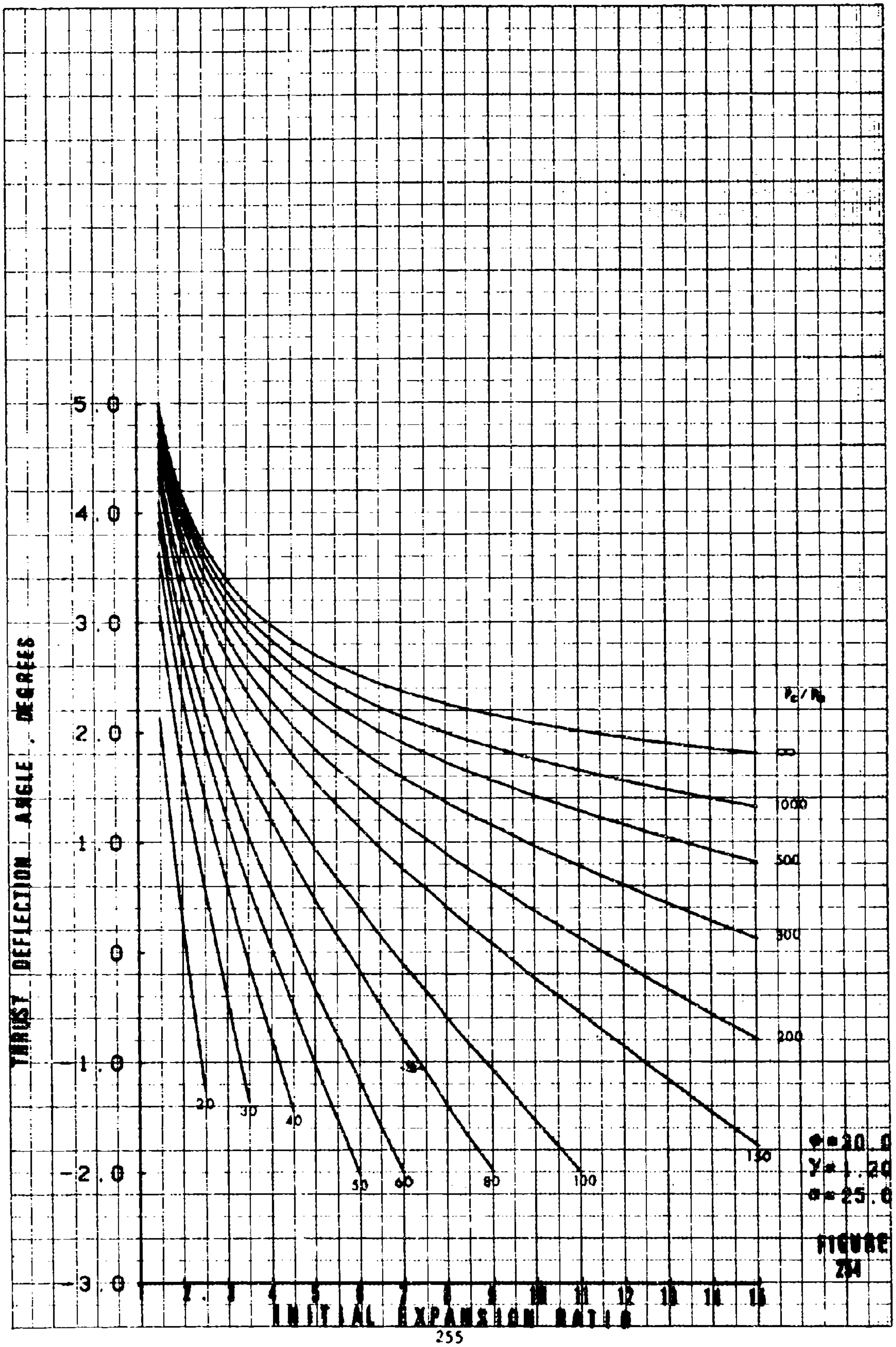

NON-DIMENSIONAL MOMENT
1.00
.75
.50
.25
0
-.25
-.50
-.75
-1.00
-1.25
-1.50
INITIAL EXPANSION RATIO
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
∞
1000
500
300
200
150
100
20
30
40
50
60
80
Φ = 20.0
γ = 1.20
α = 25.0

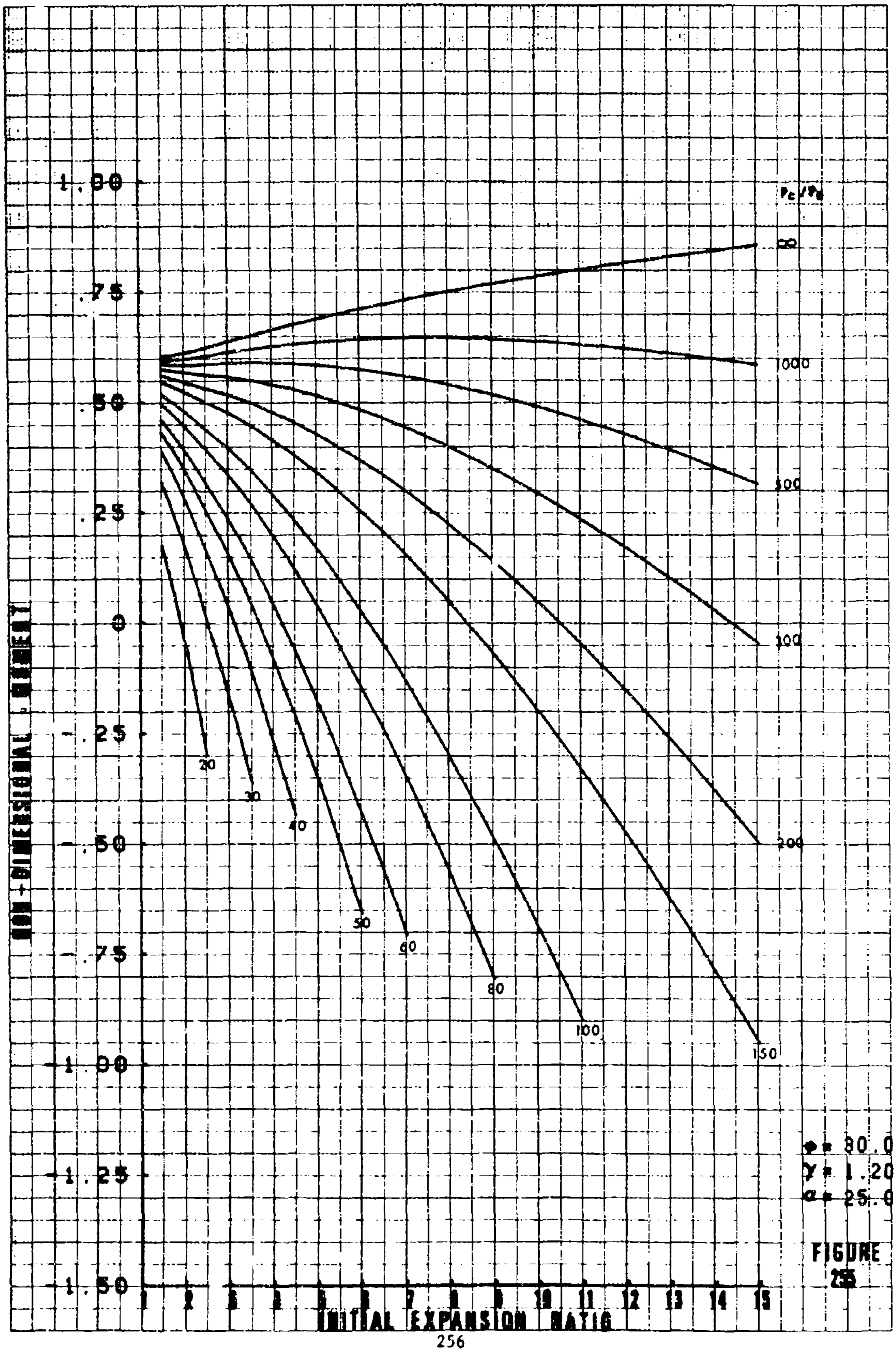
FIGURE 252



THRUST COEFFICIENT
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
INITIAL EXPANSION RATIO
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
1000
500
300
200
150
100
80
60
50
40
30
20
φ= 30.0
γ= 1.20
α= 25.0

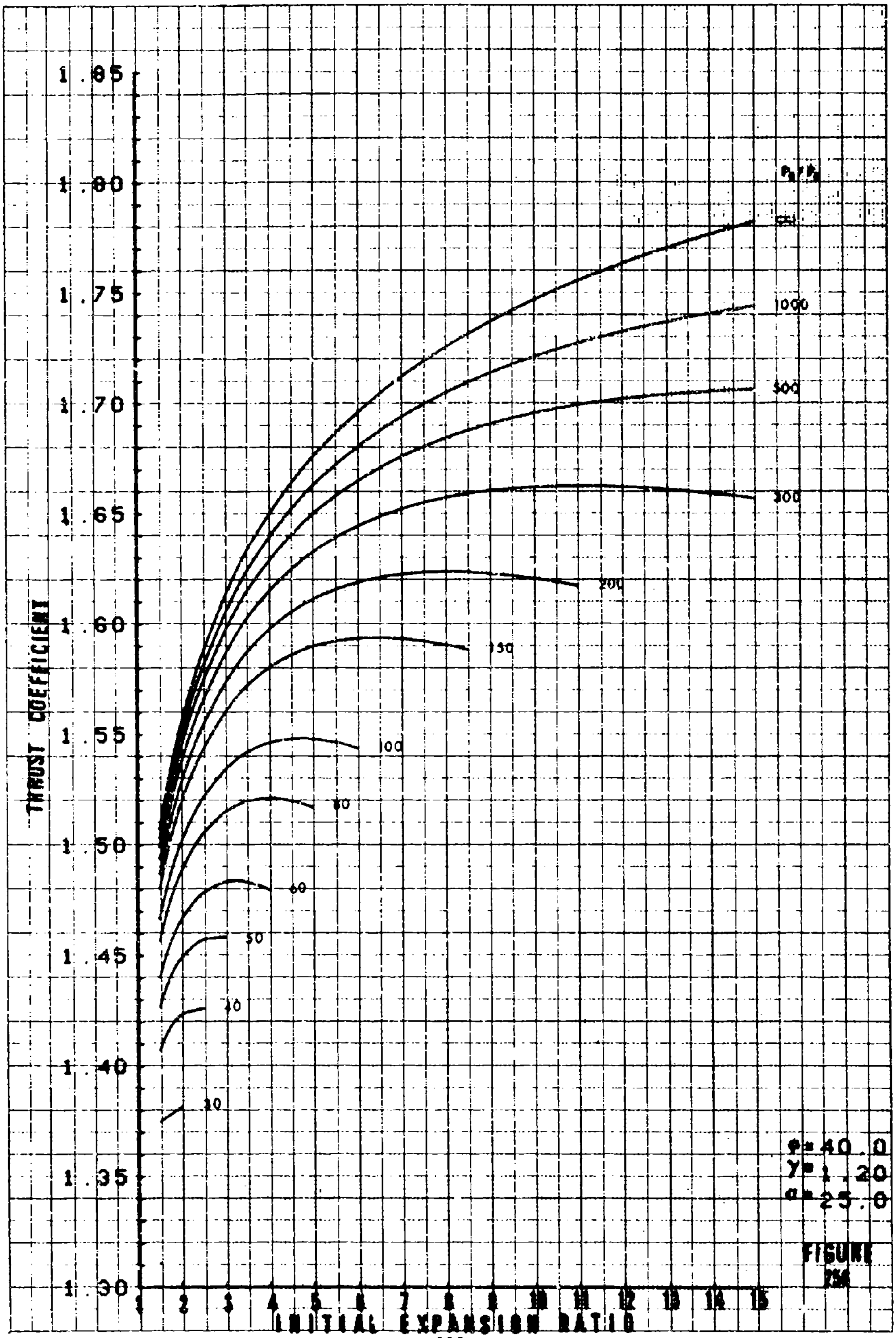
FIGURE 251

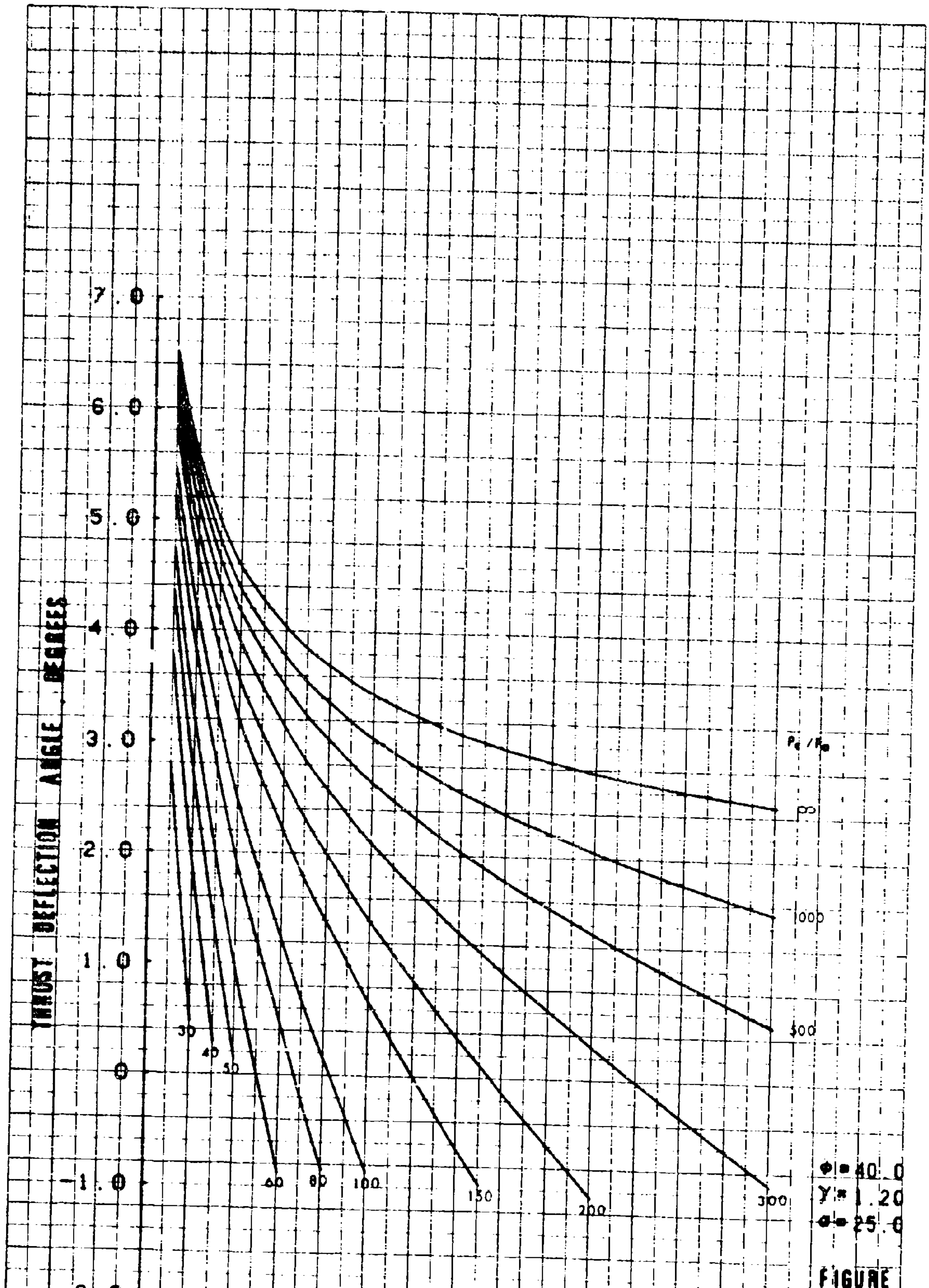

THRUST DEFLECTION ANGLE, DEGREES
5.0
4.0
3.0
2.0
1.0
0
-1.0
-2.0
-3.0
INITIAL EXPANSION RATIO
P_c/P_a
∞
1000
500
300
200
150
100
80
60
50
40
30
20
φ = 30.0
γ = 1.20
α = 25.0
FIGURE
234



1.00
.75
.50
.25
0
-.25
-.50
-.75
-1.00
-1.25
-1.50
NON-DIMENSIONAL MOMENT
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
P_c/P_a
∞
1000
500
100
200
150
100
80
60
50
40
30
20
ϕ = 80.0
γ = 1.20
α = 25.0

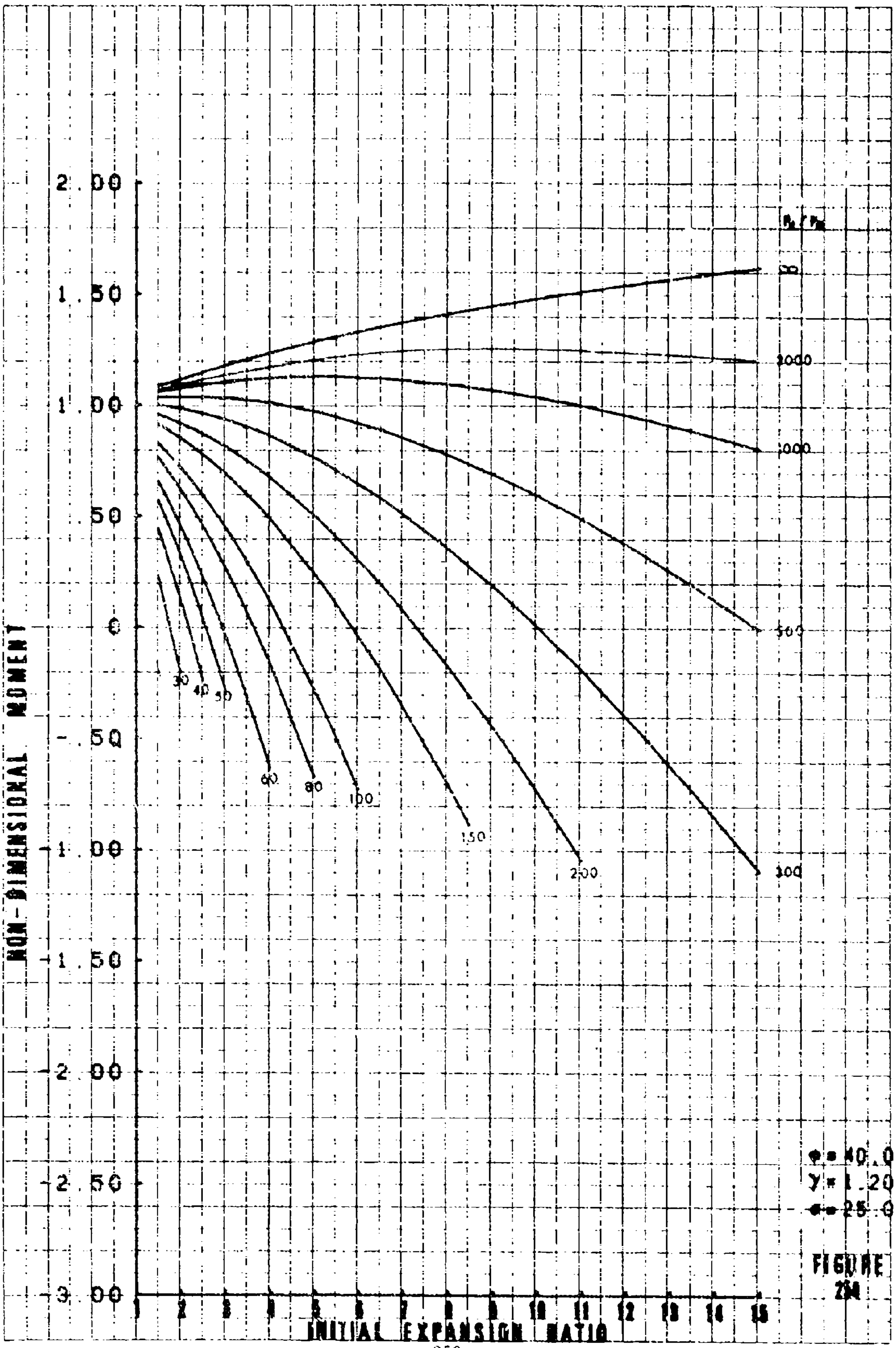
FIGURE 255


THRUST COEFFICIENT
INITIAL EXPANSION RATIO
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
1000
500
300
200
150
100
80
60
50
40
30
φ= 40.0
γ= 1.20
α= 25.0
FIGURE

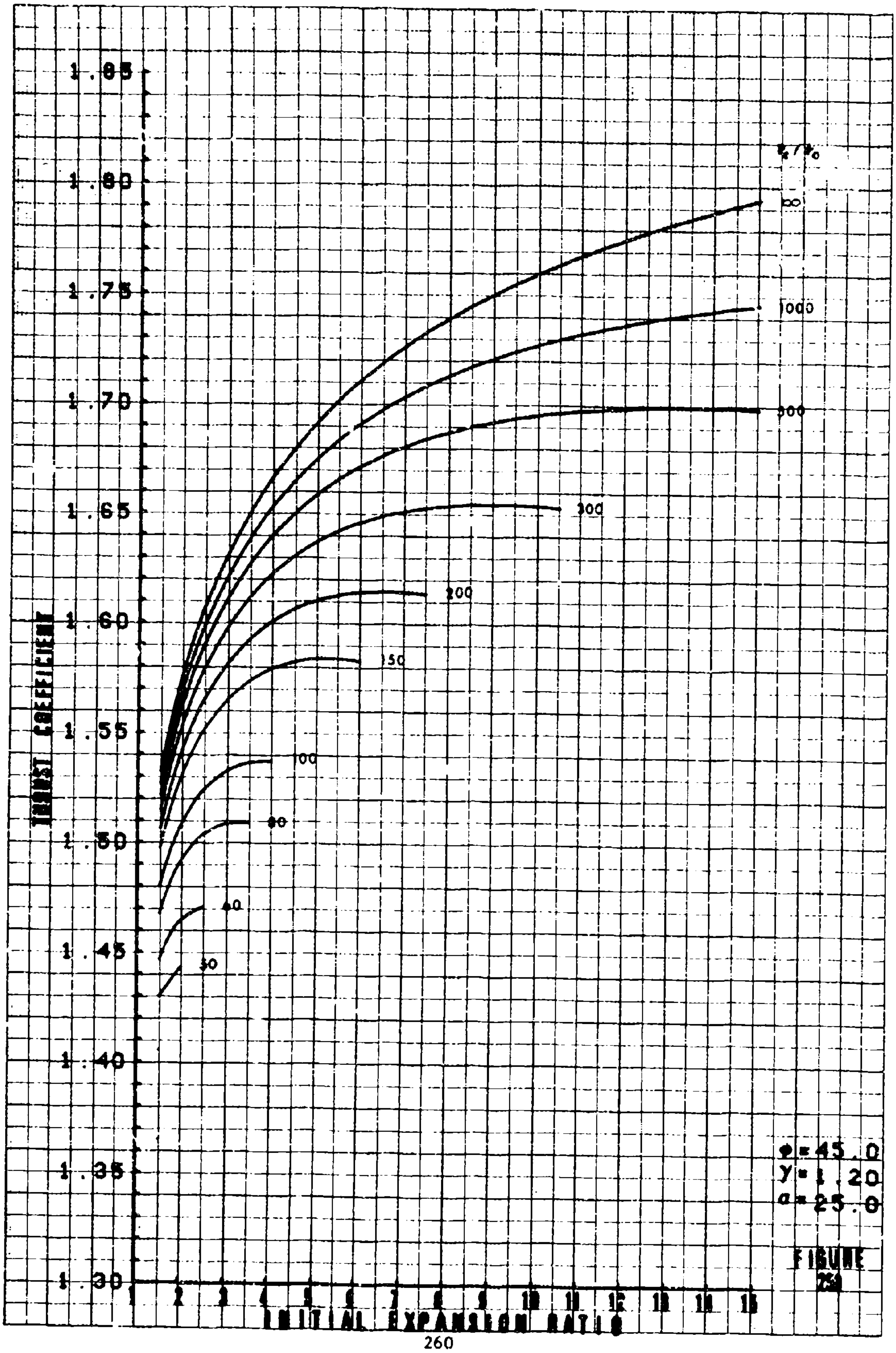


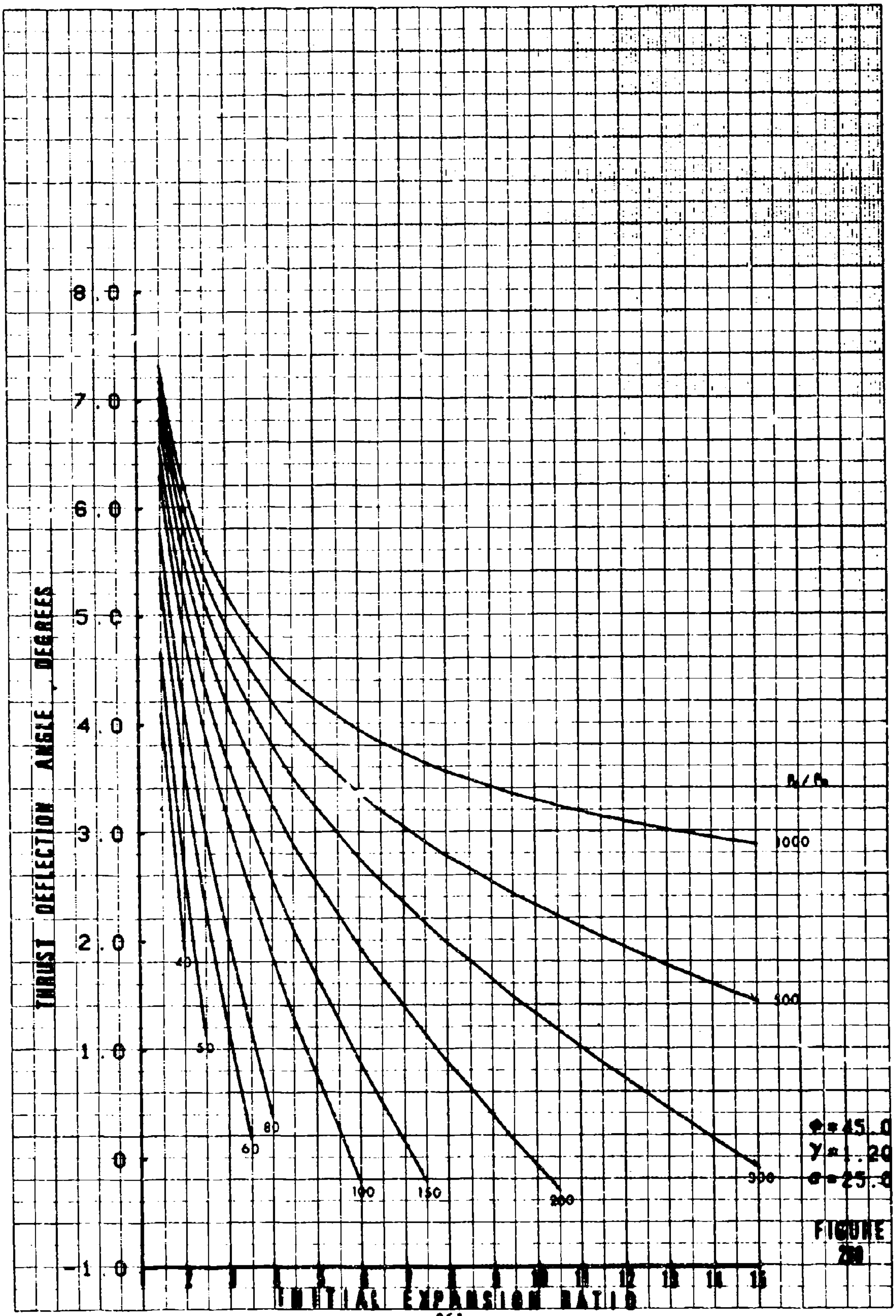
THRUST DEFLECTION ANGLE, DEGREES
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
-1.0
-2.0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
P_c/P_∞
∞
1000
500
300
200
150
100
80
60
50
40
30
Φ = 40.0
γ = 1.20
σ = 25.0

FIGURE 257

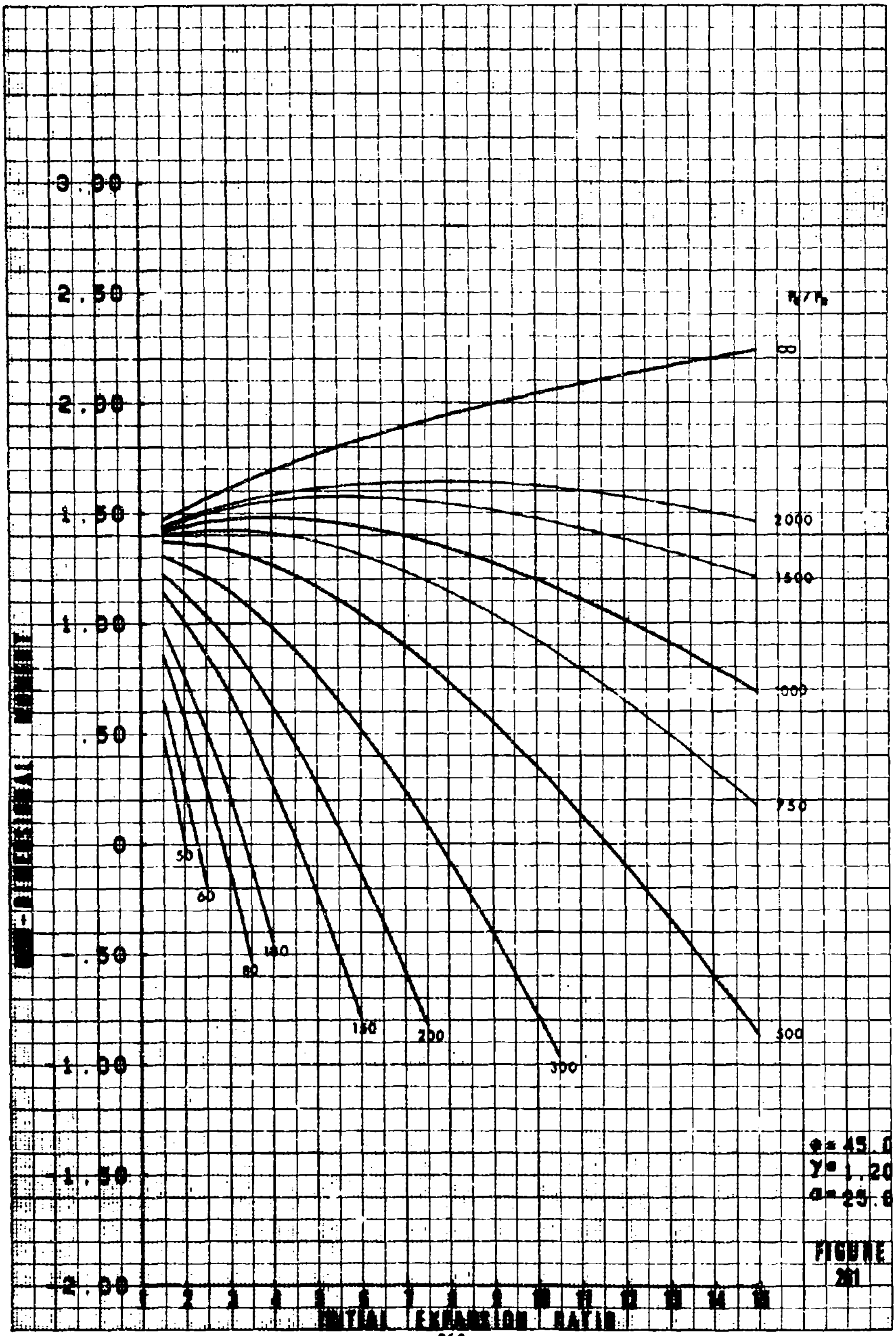


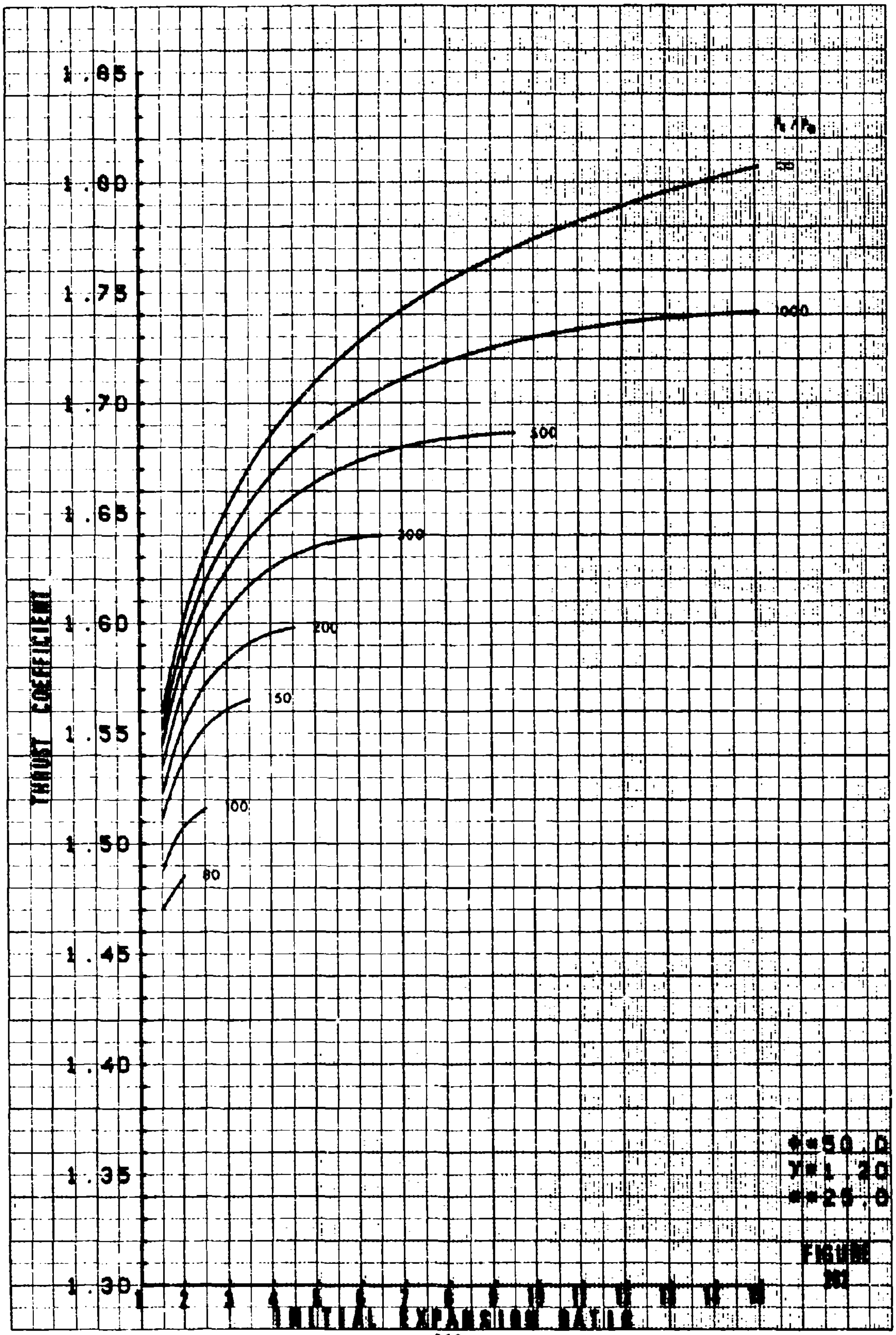
2.00
1.50
1.00
.50
0
-.50
-1.00
-1.50
-2.00
-2.50
-3.00
NON-DIMENSIONAL MOMENT
INITIAL EXPANSION RATIO
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
30
40
50
60
80
100
150
200
300
500
1000
2000

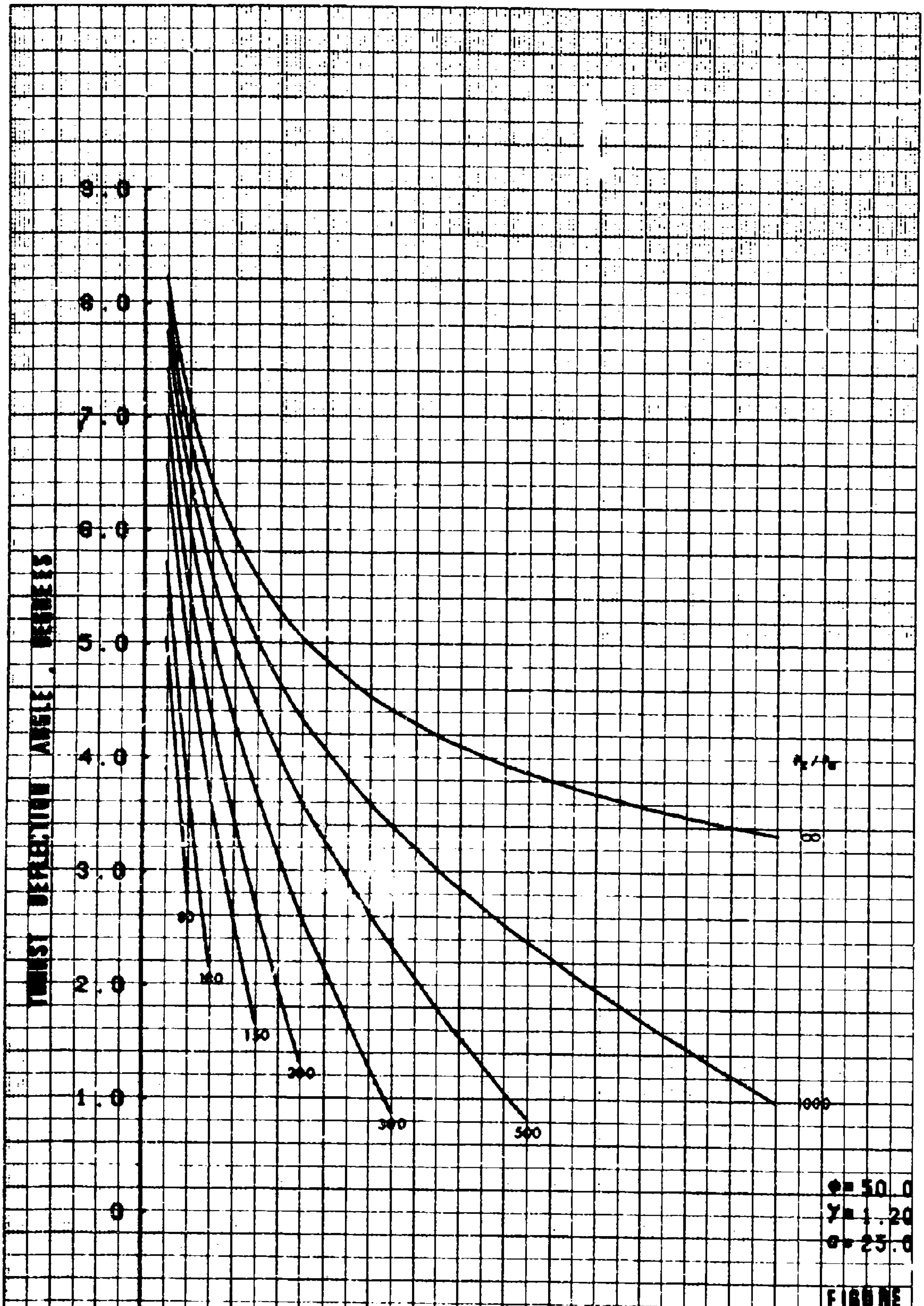

THRUST COEFFICIENT
INITIAL EXPANSION RATIO
1.30
1.35
1.40
1.45
1.50
1.55
1.60
1.65
1.70
1.75
1.80
1.85
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
∞
1000
500
300
200
150
100
80
40
30
φ = 45.0
γ = 1.20
a = 25.0
FIGURE

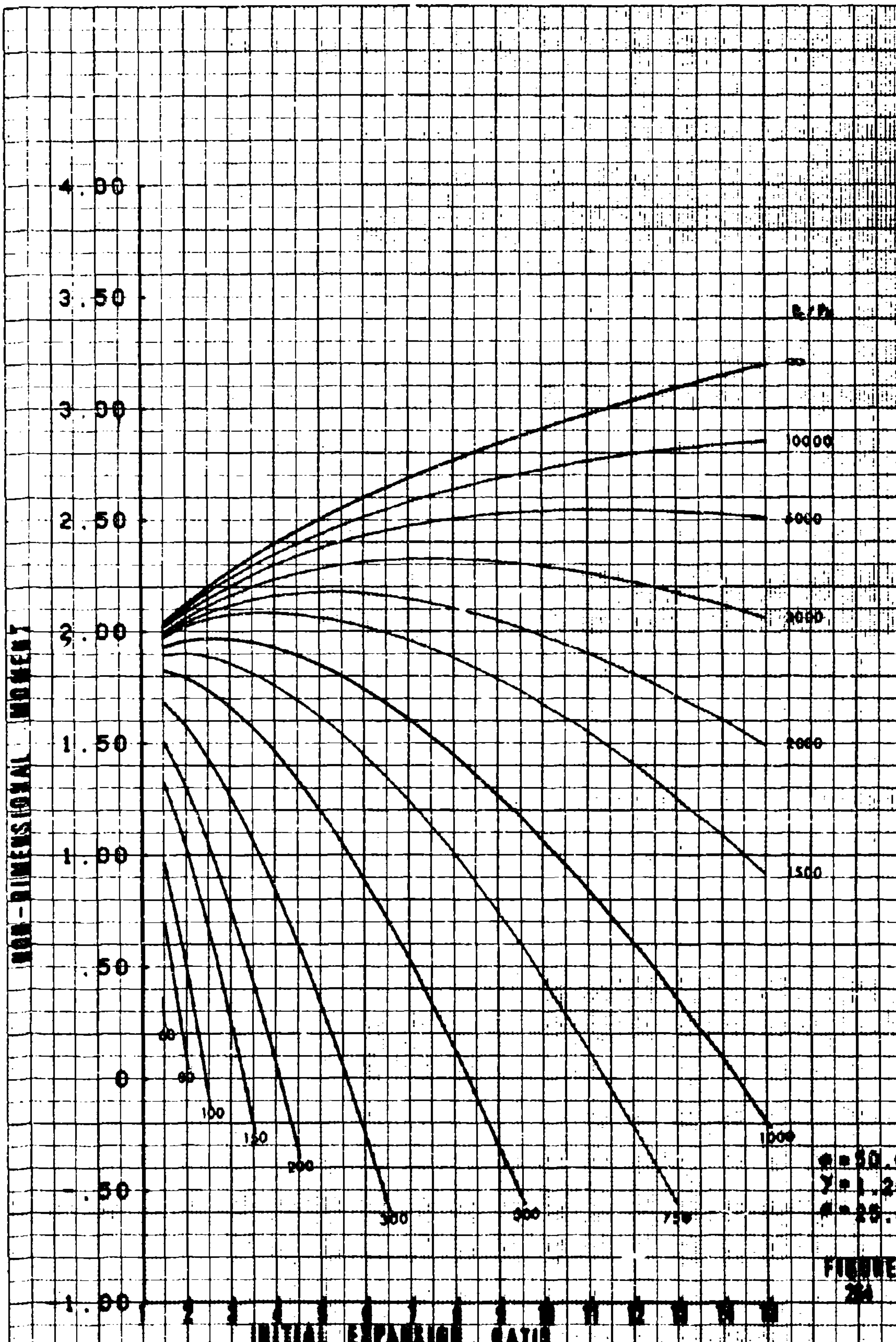


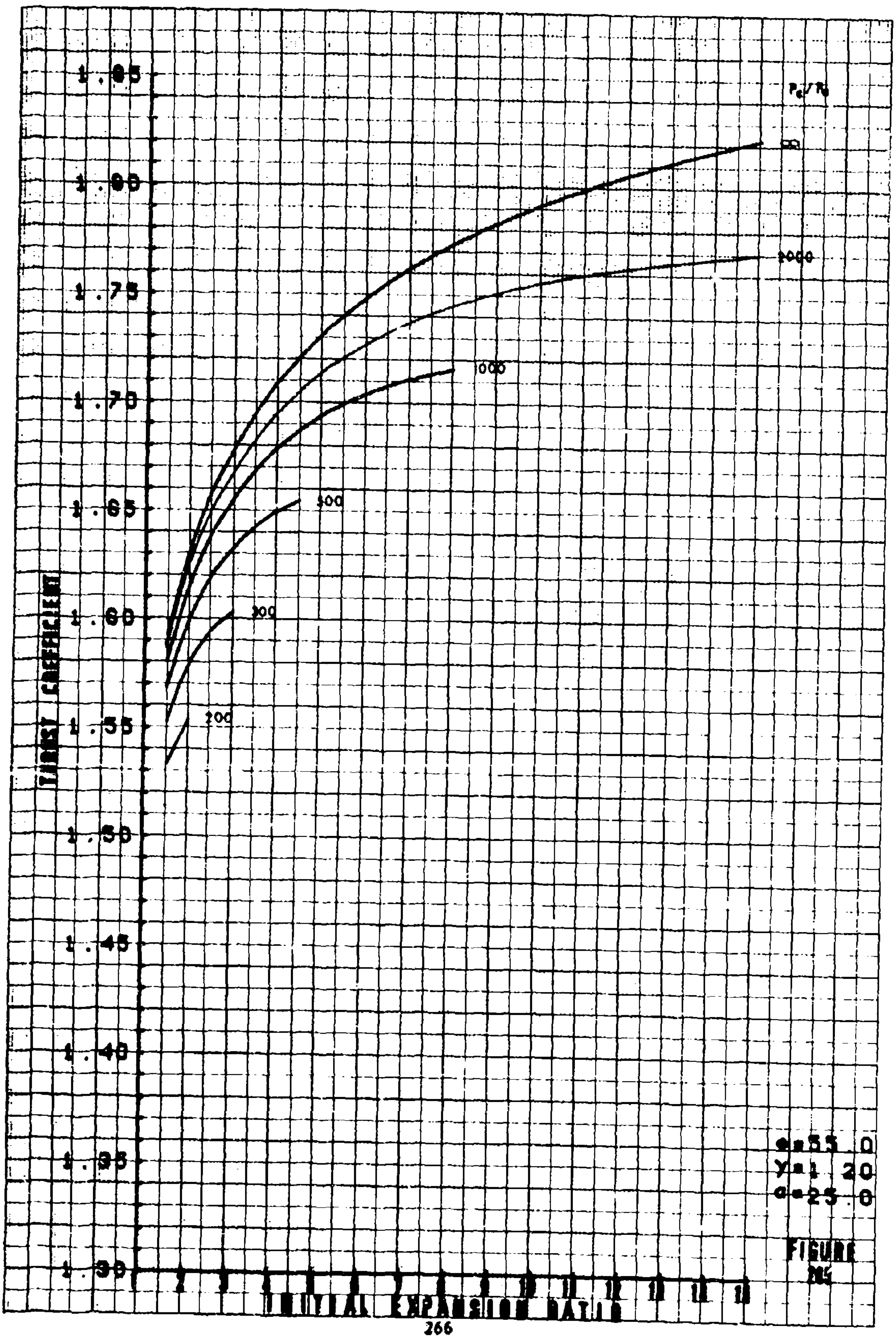
THRUST DEFLECTION ANGLE, DEGREES
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
-1.0
2
3
4
5
6
7
8
9
10
11
12
13
14
15
INITIAL EXPANSION RATIO
1000
500
300
200
150
100
80
60
50
40


3.00
2.50
2.00
1.50
1.00
.50
0
-.50
-1.00
-1.50
-2.00
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
∞
2000
1500
1000
750
500
300
200
150
100
80
60
50
φ= 45.0
γ= 1.20
FIGURE

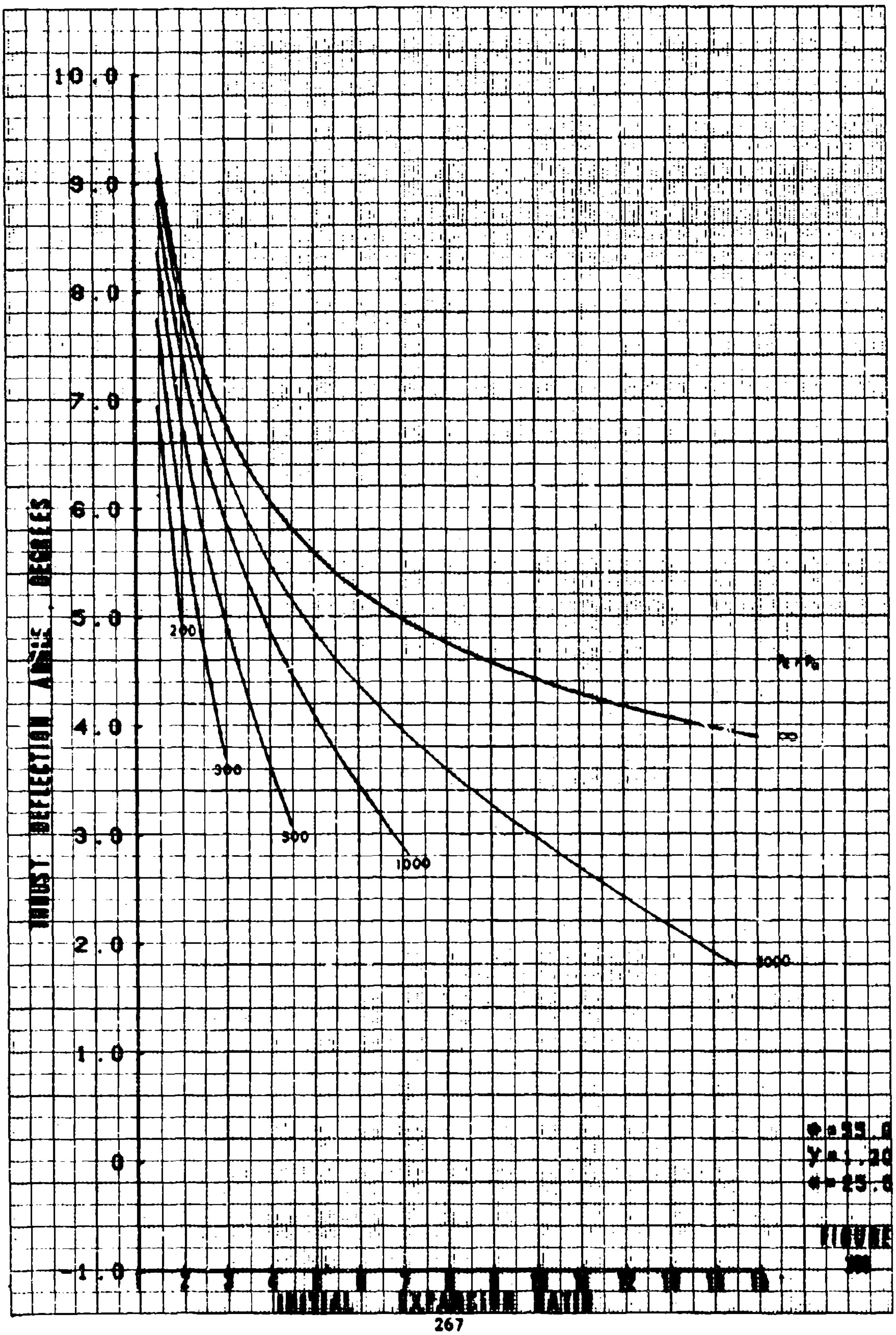

THRUST COEFFICIENT
INITIAL EXPANSION RATIO
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
1000
500
300
200
150
100
80
50.0
1.20
25.0
FIGURE


THRUST DEFLECTION ANGLE, DEGREES
INITIAL EXPANSION RATIO
90
100
150
200
300
500
1000
∞
Φ = 50.0
γ = 1.20
θ = 25.0
FIGURE
213


NON-DIMENSIONAL MOMENT
INITIAL EXPANSION RATIO
4.00
3.50
3.00
2.50
2.00
1.50
1.00
.50
0
-.50
-1.00
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
10000
6000
3000
2000
1500
1000
750
500
300
200
150
100
80
60
FIGURE



THRUST COEFFICIENT
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
P_c/P_a
∞
2000
1000
500
300
200
2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
FIGURE


THRUST DEFLECTION ANGLE, DEGREES
INITIAL EXPANSION RATIO
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
-1.0
200
300
500
1000
3000
∞

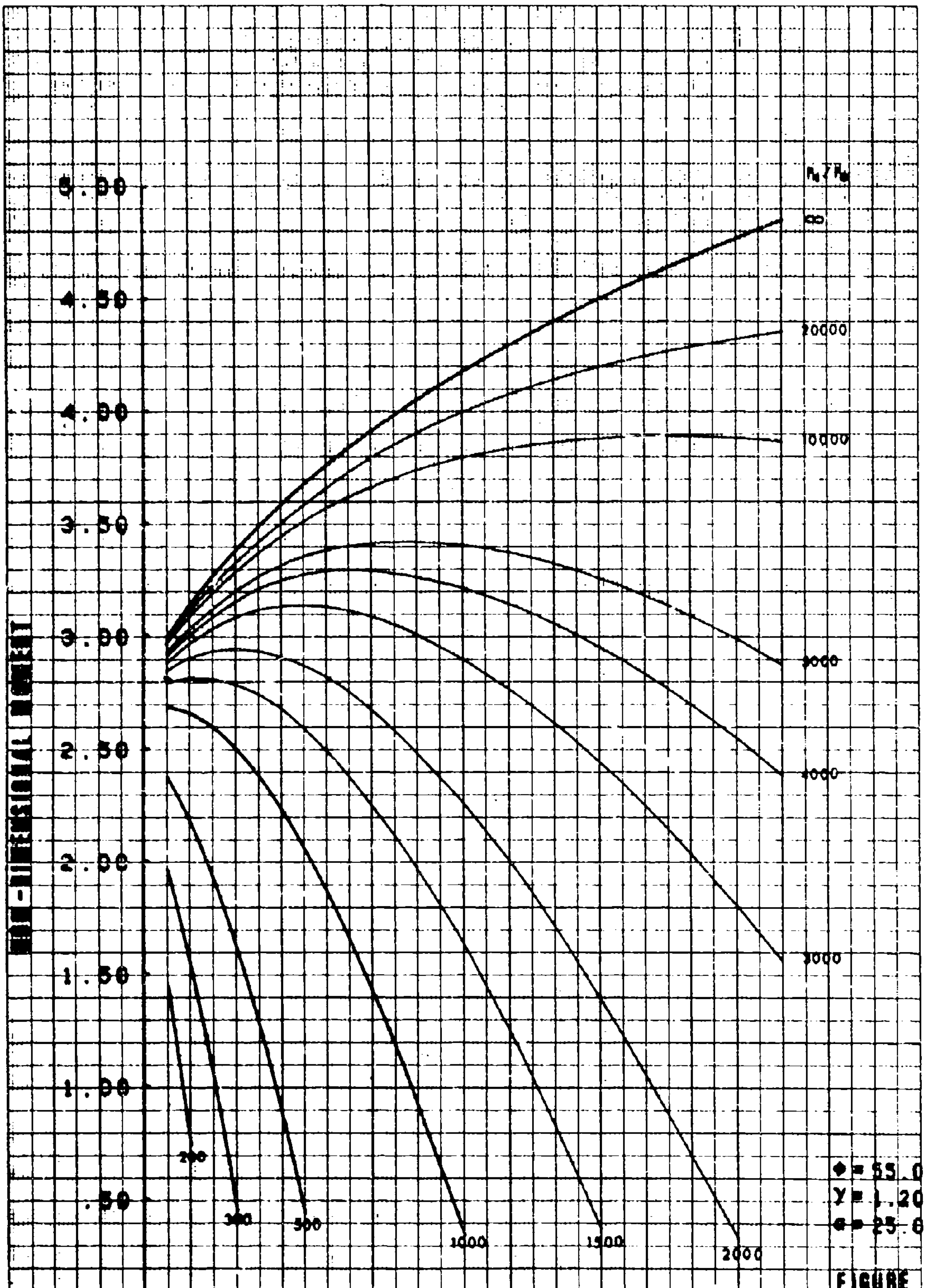
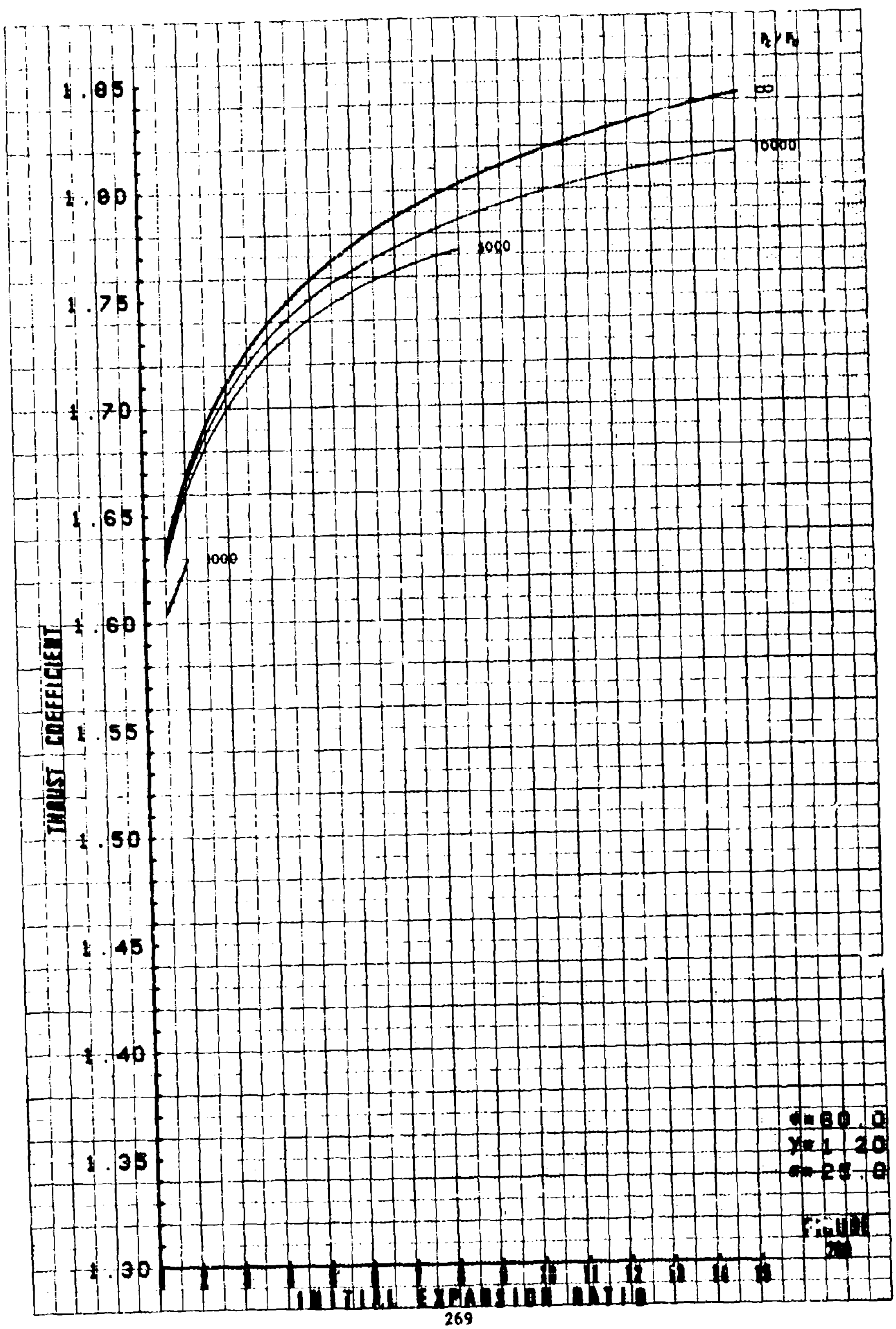
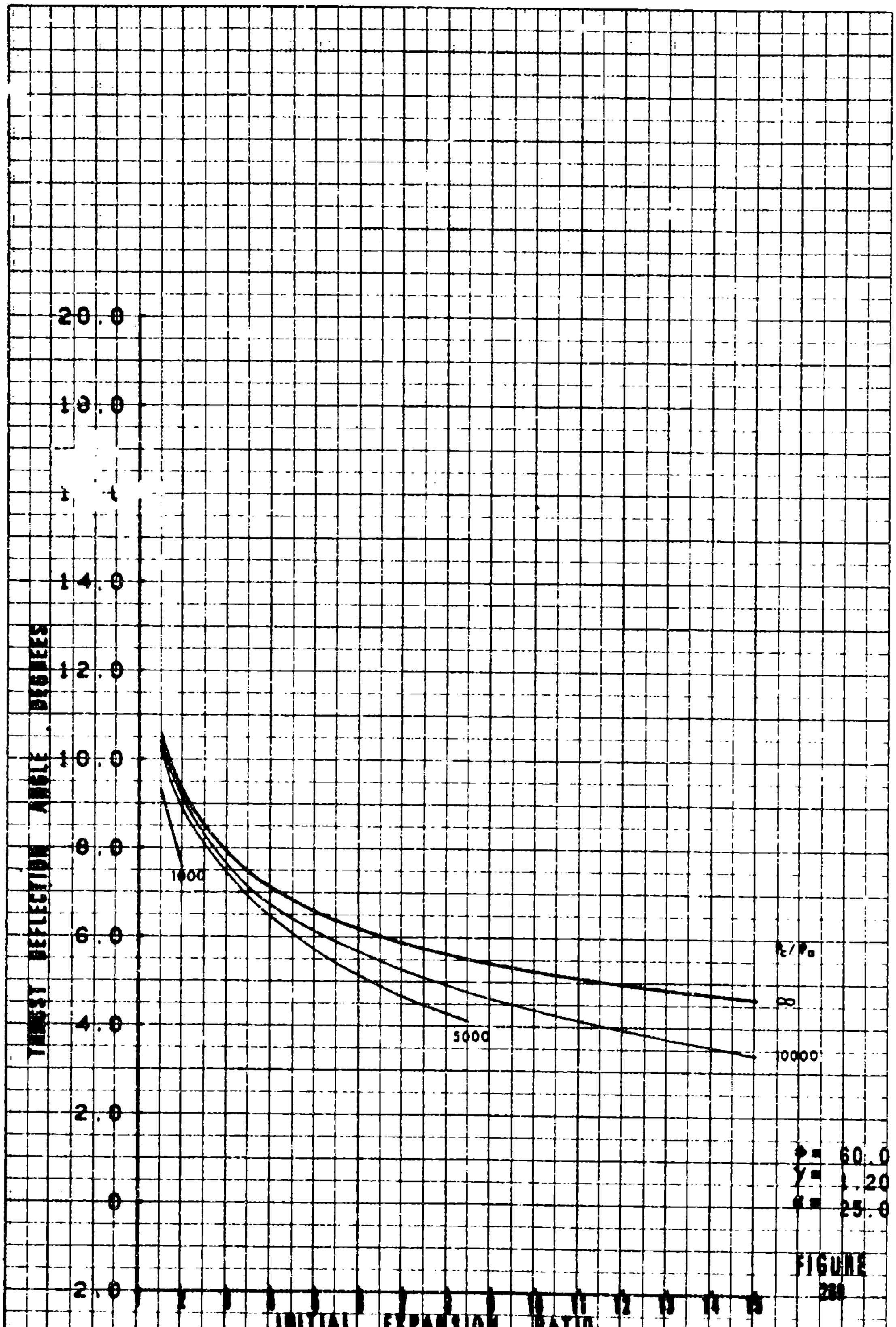
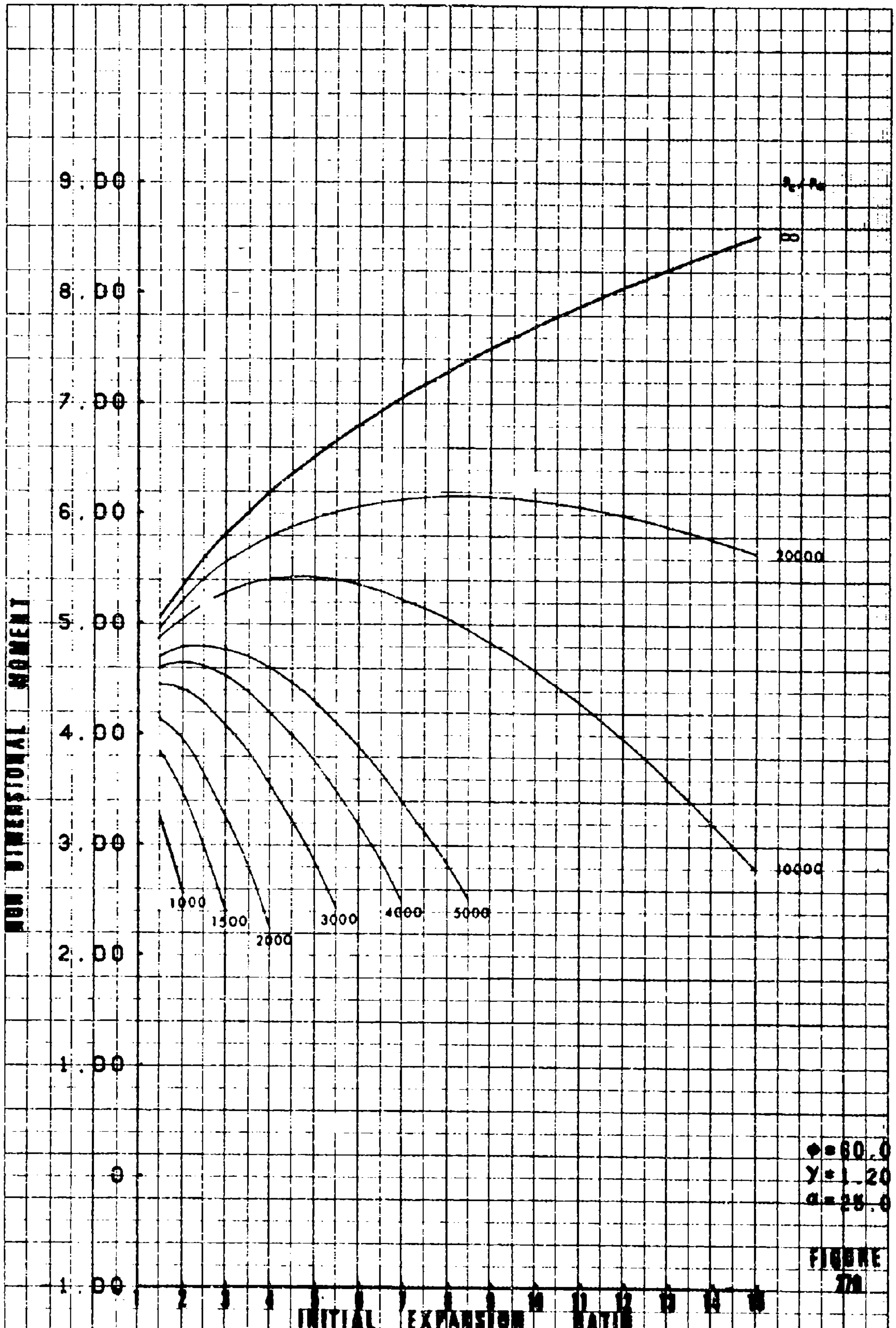

NON-DIMENSIONAL MOMENT
INITIAL EXPANSION RATIO
0
.50
1.00
1.50
2.00
2.50
3.00
3.50
4.00
4.50
5.00
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
∞
20000
10000
5000
4000
3000
2000
1500
1000
500
300
200
Φ = 55.0
γ = 1.20
α = 25.8

FIGURE 287

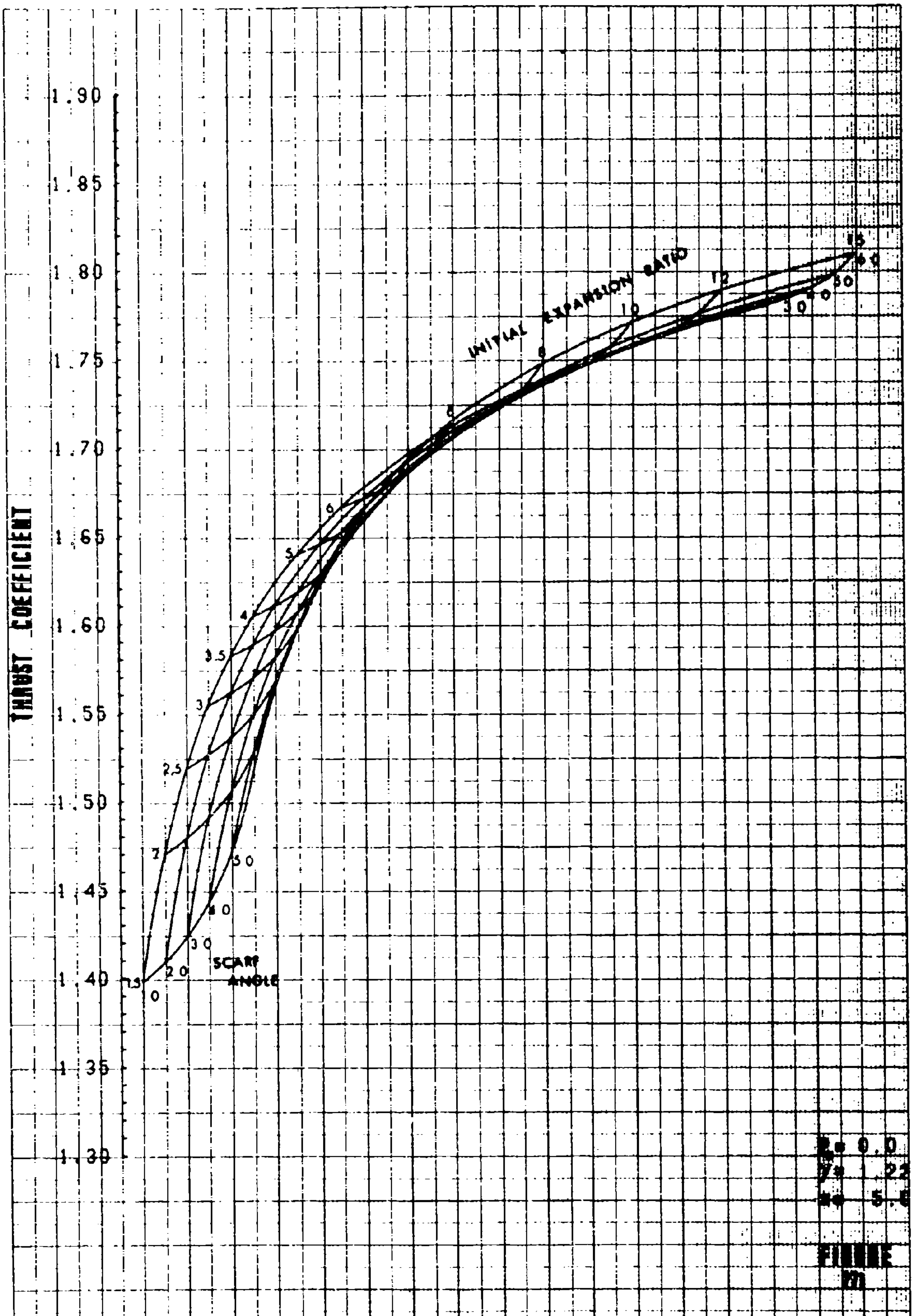

THRUST COEFFICIENT
INITIAL EXPANSION RATIO
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
10000
5000
1000
FIGURE

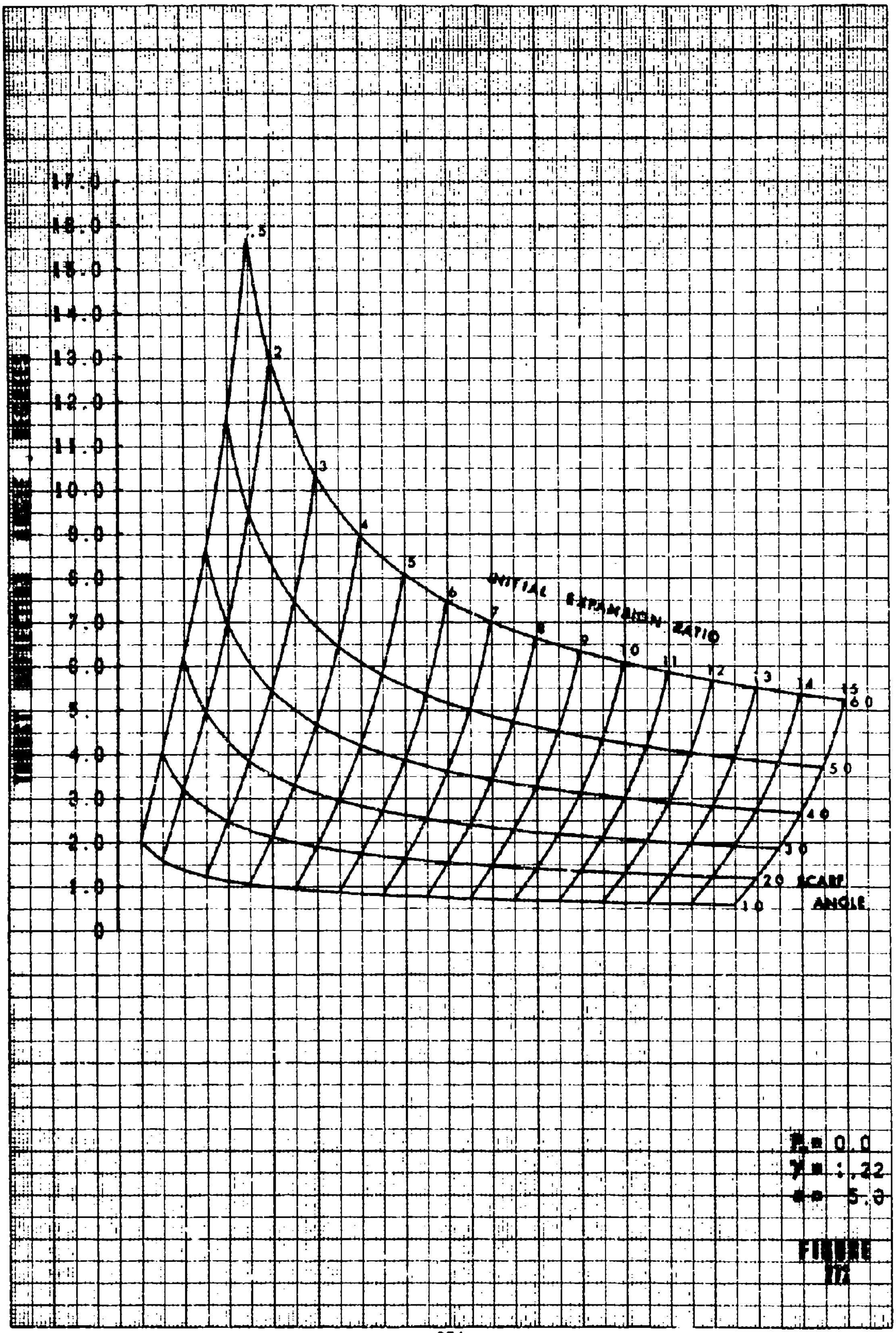

THRUST DEFLECTION ANGLE, DEGREES
20.0
18.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0
2.0
INITIAL EXPANSION RATIO
1000
5000
10000
∞
P_c/P_a
φ = 60.0
γ = 1.20
α = 25.0
FIGURE



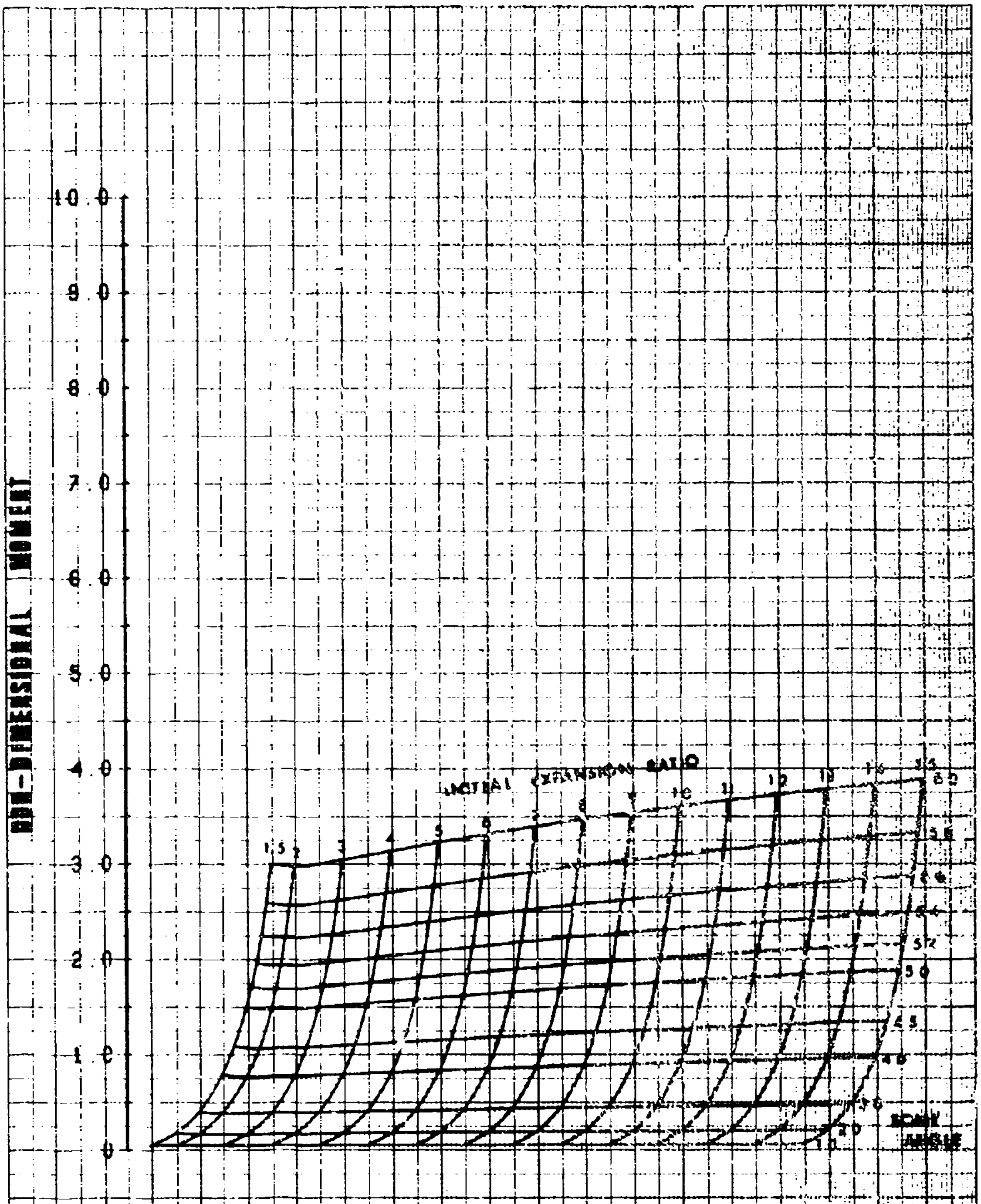
9.00
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0
1.00
NON DIMENSIONAL MOMENT
INITIAL EXPANSION RATIO
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
P_c/P_a
∞
20000
10000
1000
1500
2000
3000
4000
5000
φ = 60.0
γ = 1.20
α = 25.0

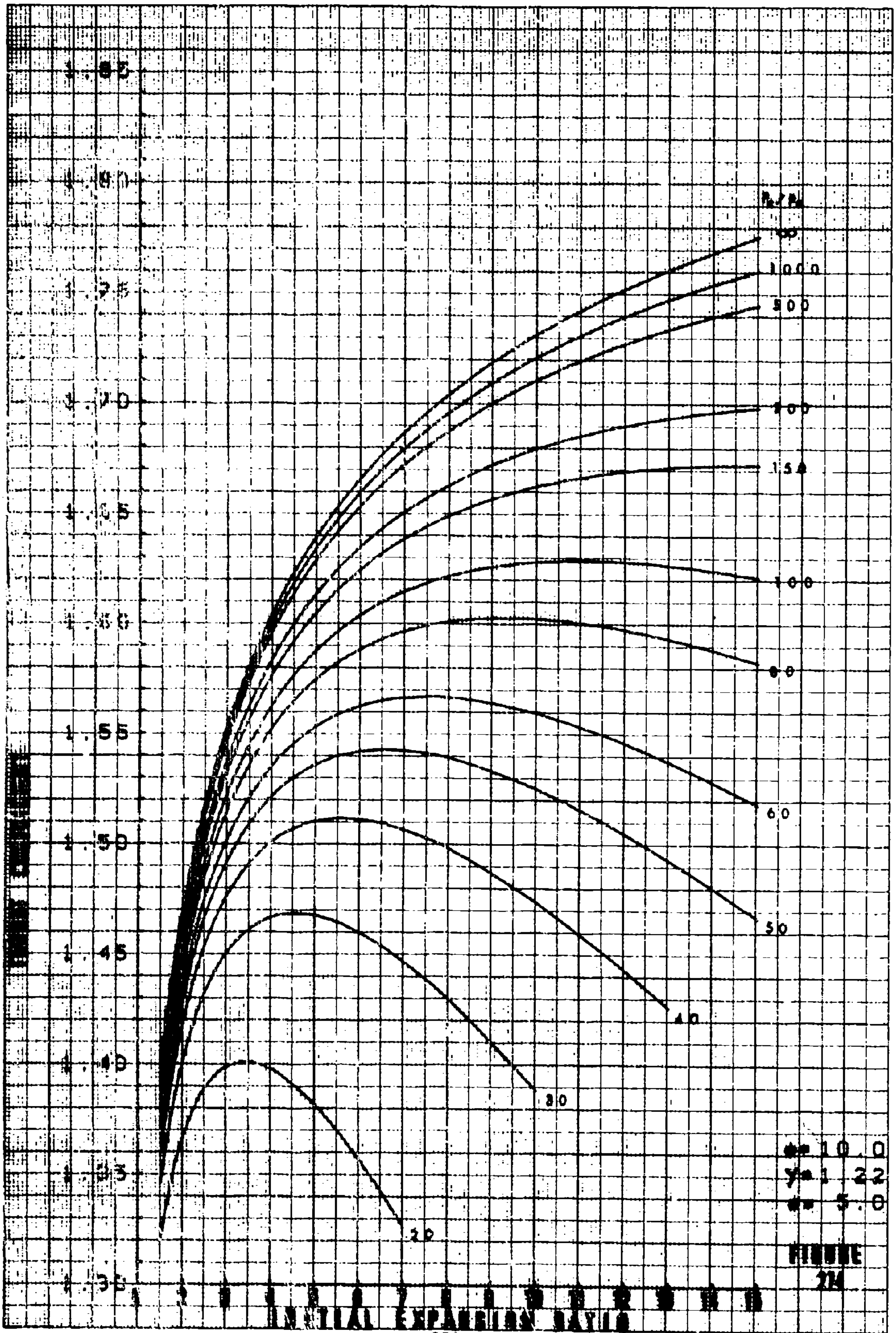
FIGURE 271


THRUST COEFFICIENT
1.90
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
INITIAL EXPANSION RATIO
SCARF ANGLE
FIGURE

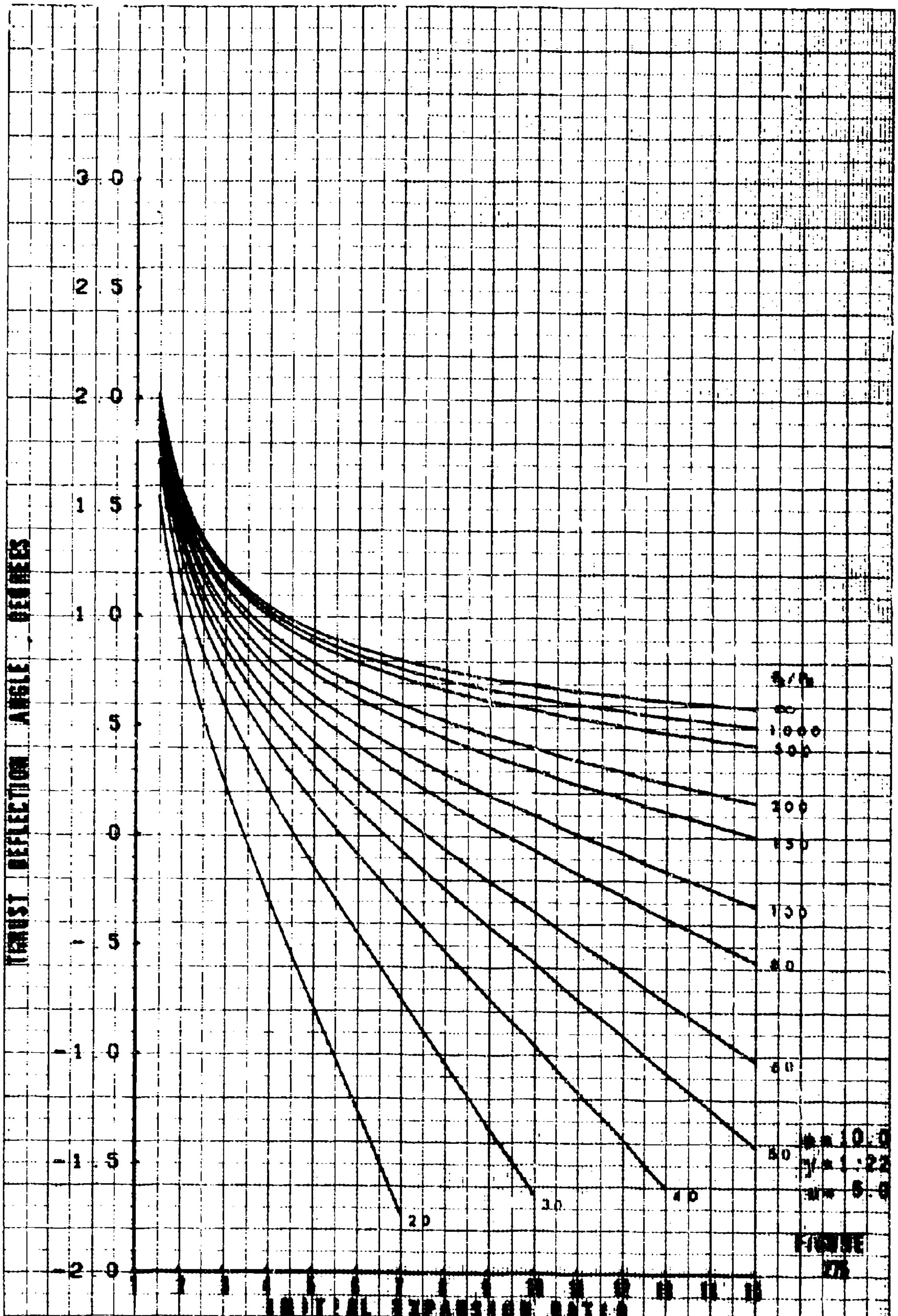


INITIAL EXPANSION RATIO
SCARF ANGLE


NON-DIMENSIONAL MOMENT
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
NOZZLE EXPANSION RATIO
BOAT ANGLE
FIGURE



1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
1000
500
200
150
100
80
60
50
40
30
20
10.0
1.22
5.0
FIGURE
INITIAL EXPANSION RATIO


THRUST DEFLECTION ANGLE DEGREES
3.0
2.5
2.0
1.5
1.0
.5
0
-.5
-1.0
-1.5
-2.0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
INITIAL EXPANSION RATIO
1,000
200
150
100
80
60
50
20
30
40
FIGURE

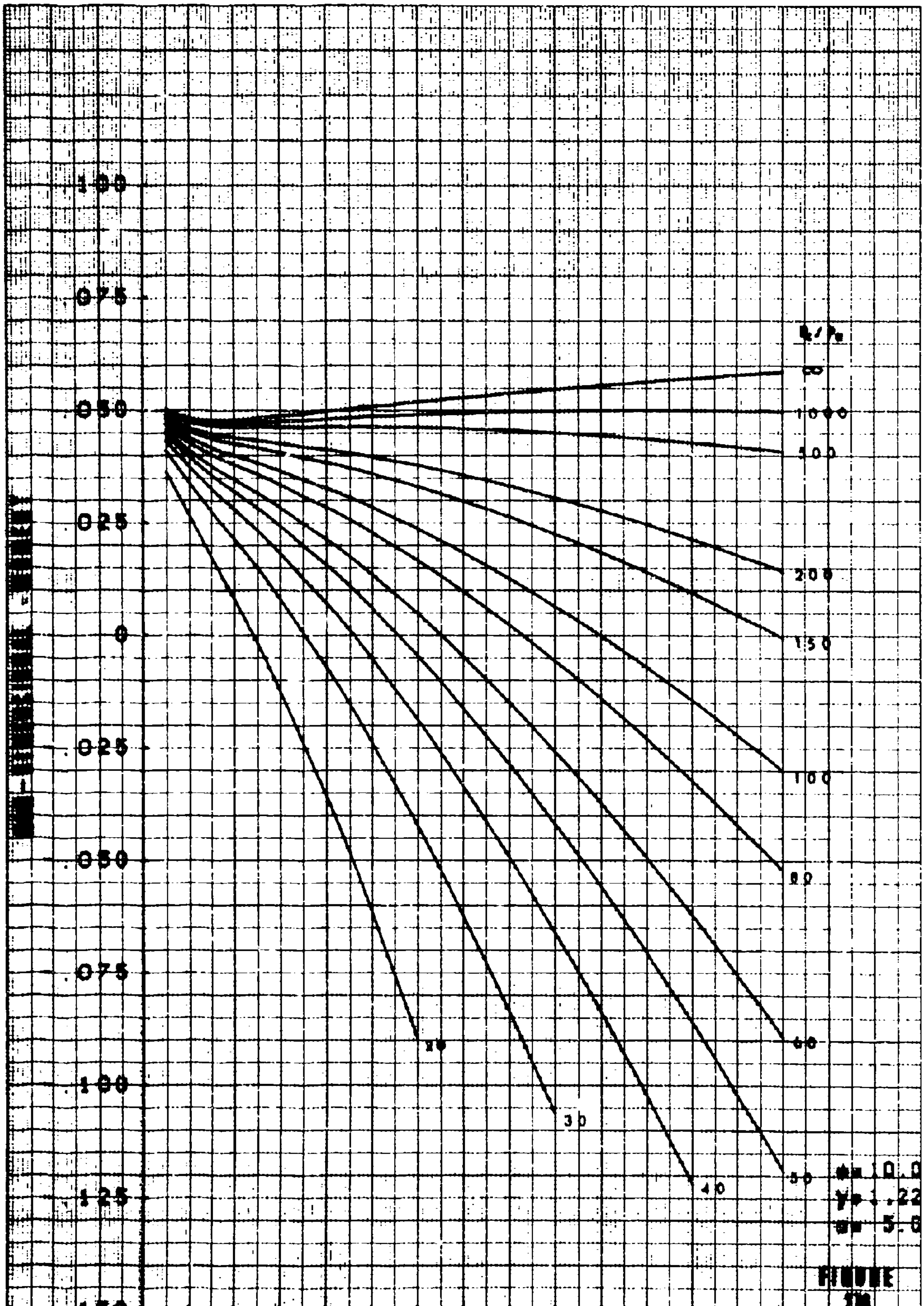
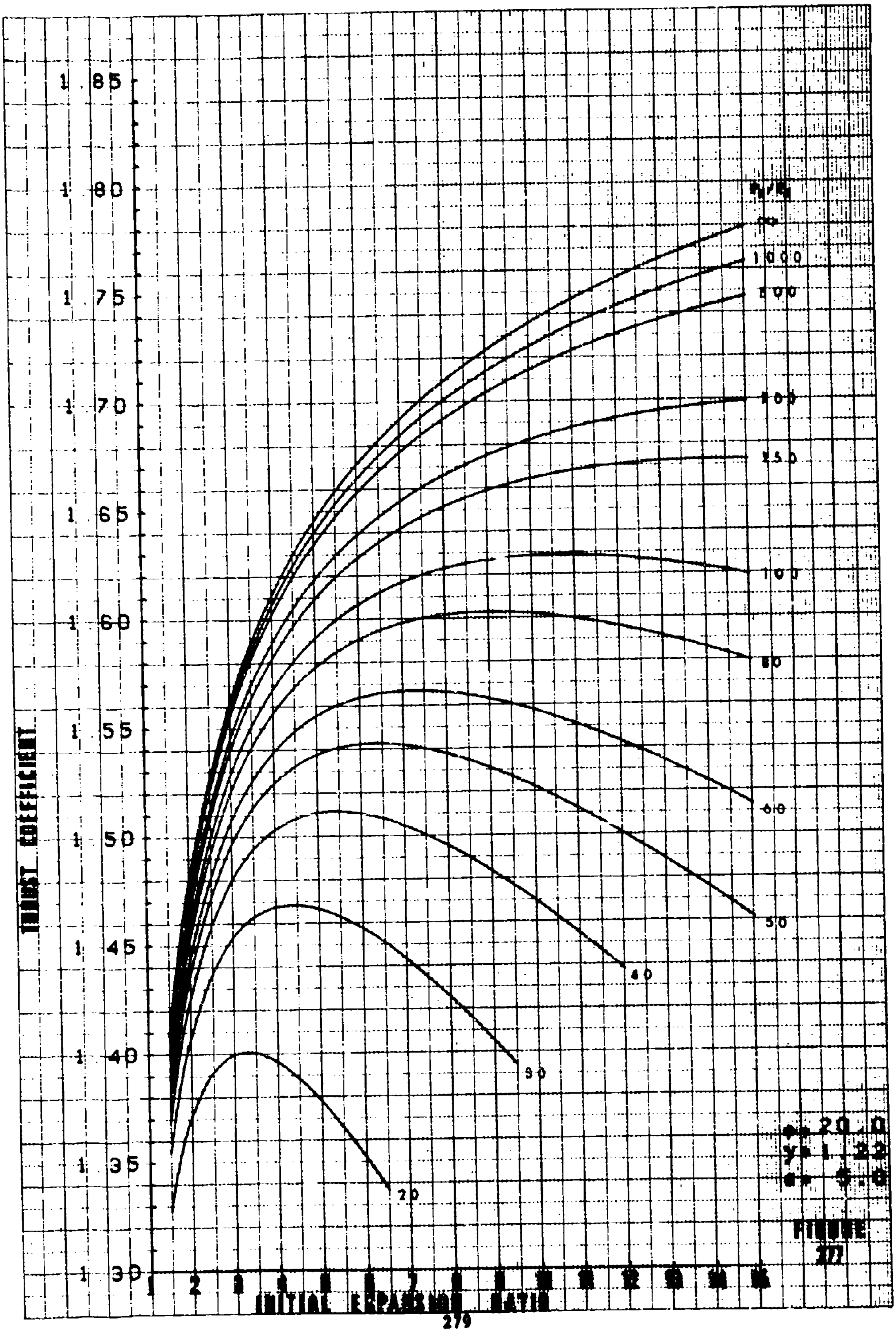
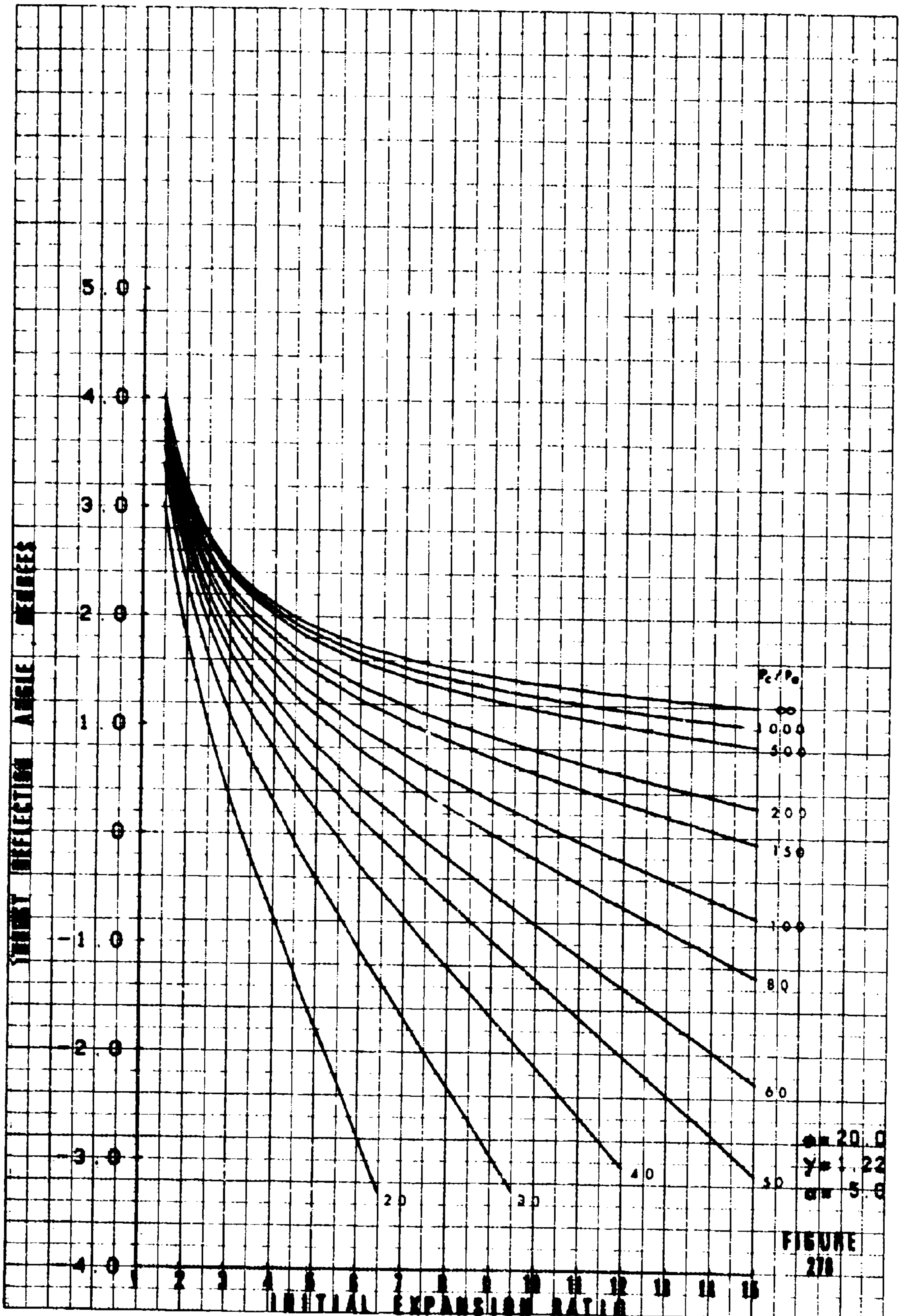

.100
.075
.050
.025
0
.025
.050
.075
.100
.125
.150
P_c/P_a
∞
1000
500
200
150
100
80
60
50
40
30
20
ε = 10.0
γ = 1.22
m = 5.0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO

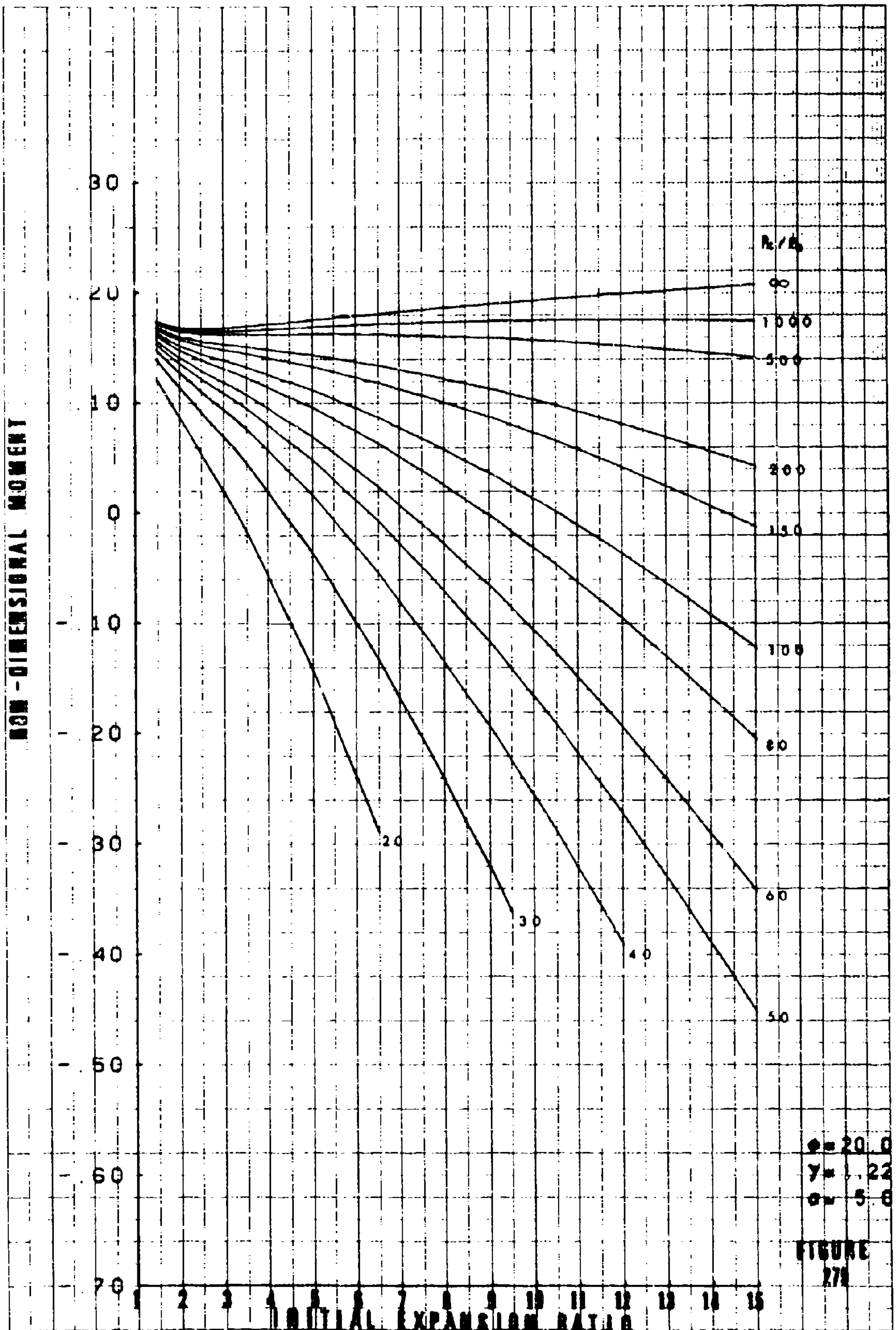
FIGURE 216



1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
THRUST COEFFICIENT
INITIAL EXPANSION RATIO
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
1000
500
200
150
100
80
60
50
40
30
20

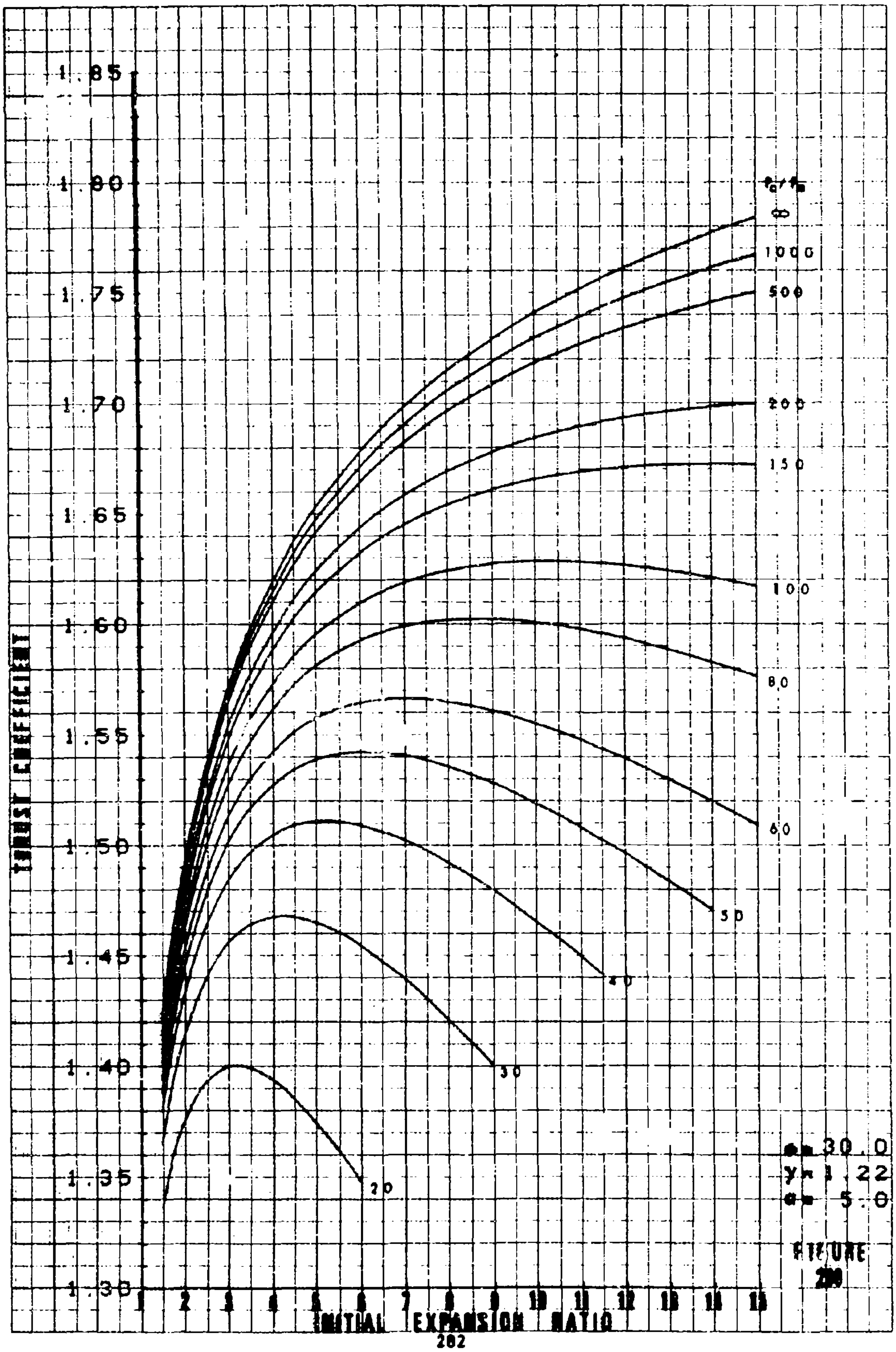
FIGURE 277

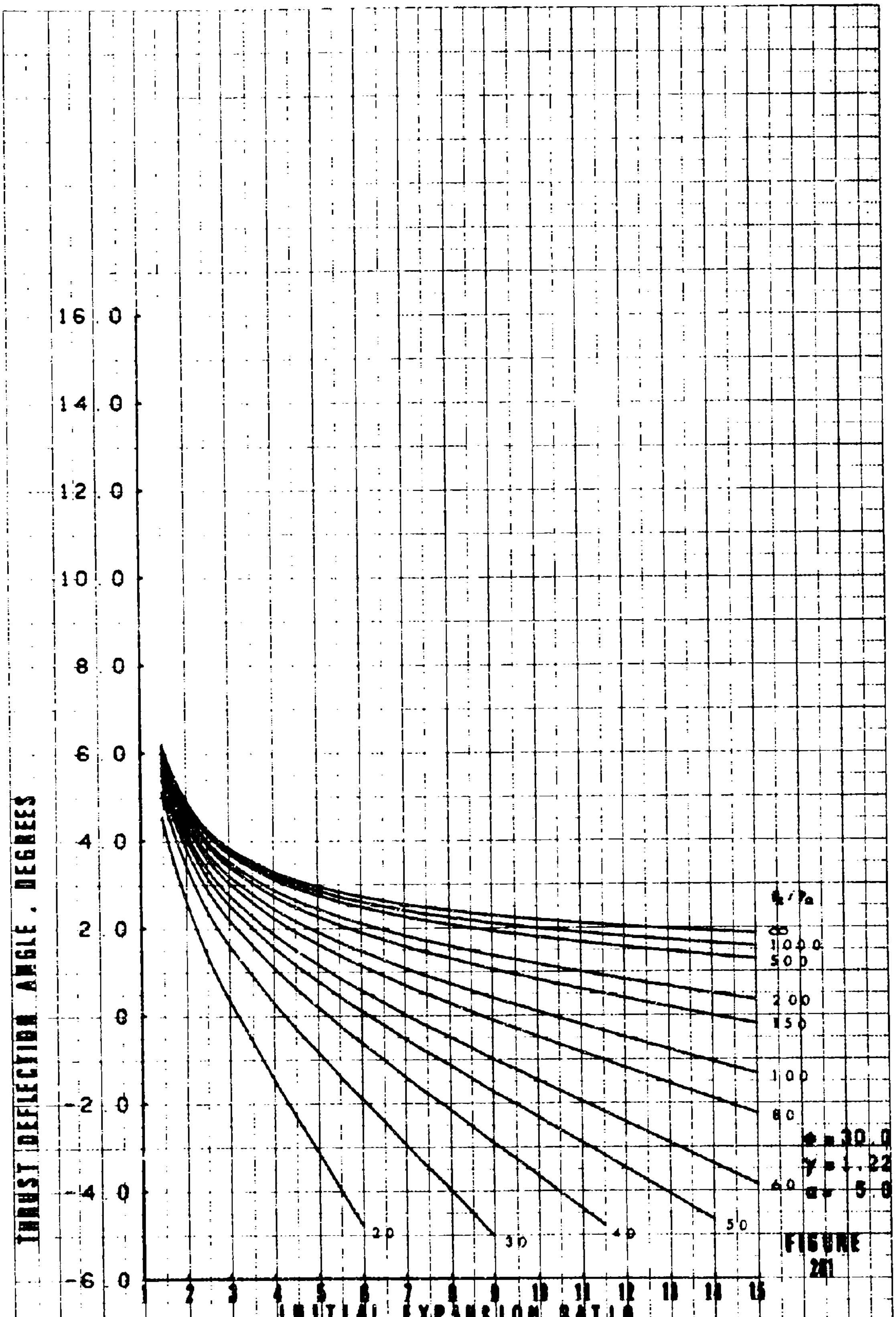

THRUST DEFLECTION ANGLE DEGREES
5.0
4.0
3.0
2.0
1.0
0
-1.0
-2.0
-3.0
-4.0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
Pc/Pe
∞
1000
500
200
150
100
80
60
50
40
30
20
θ= 20.0
γ= 1.22
α= 5.0
FIGURE 278



NON-DIMENSIONAL MOMENT
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
INITIAL EXPANSION RATIO
∞
1000
500
200
150
100
80
60
50
40
30
20

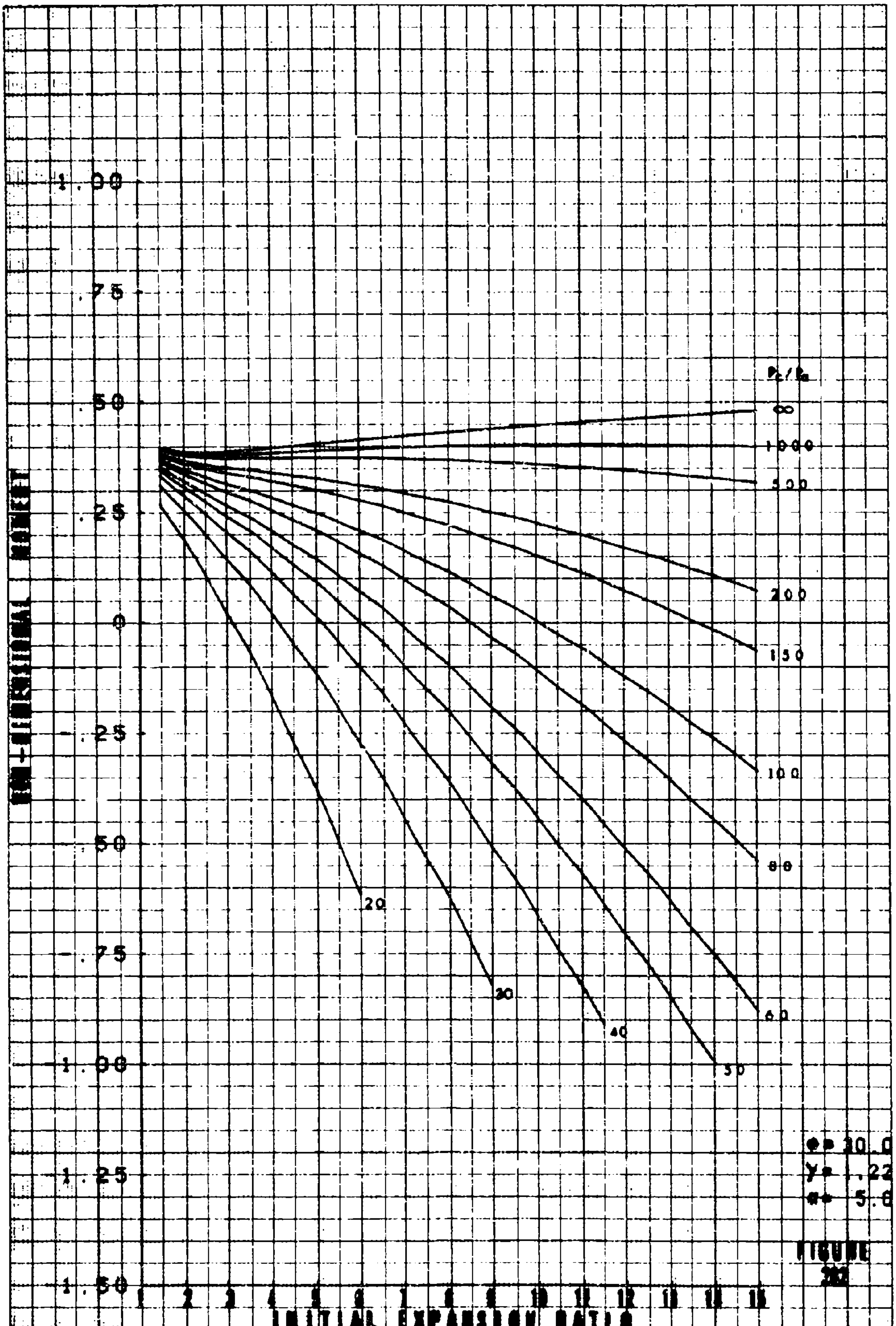
FIGURE 279


THRUST COEFFICIENT
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
INITIAL EXPANSION RATIO
p_c/p_a
∞
1000
500
200
150
100
80
60
50
40
30
20
γ = 1.22
FIGURE



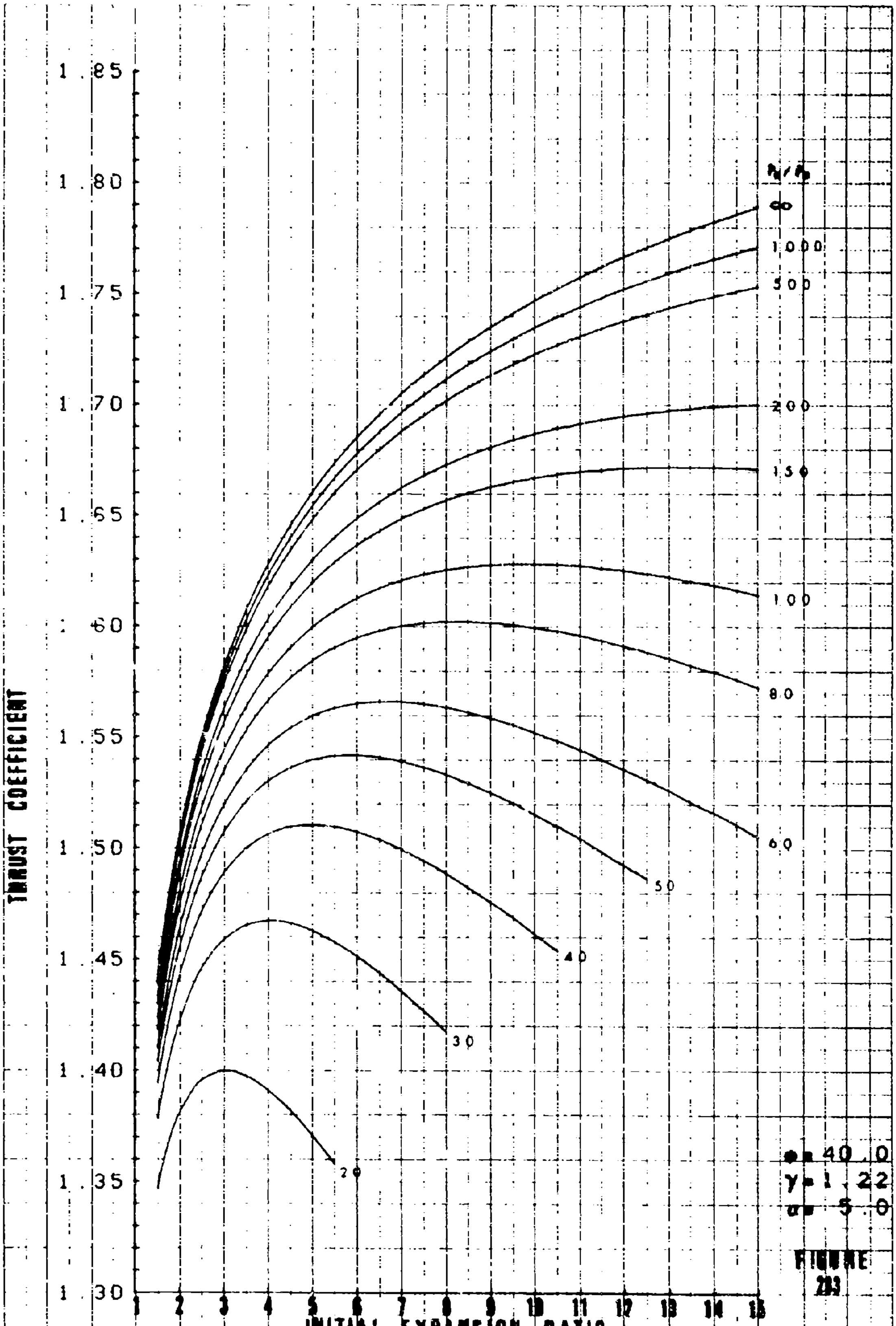
THRUST DEFLECTION ANGLE, DEGREES
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0
-2.0
-4.0
-6.0
INITIAL EXPANSION RATIO
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
∞
1000
500
200
150
100
80
60
50
40
30
20

FIGURE 211



1.00
.75
.50
.25
0
-.25
-.50
-.75
-1.00
-1.25
-1.50
P_c/P_a
∞
1000
500
200
150
100
80
60
50
40
30
20
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
NON-DIMENSIONAL MOMENT

FIGURE



1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
THRUST COEFFICIENT
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
∞
1000
500
200
150
100
80
60
50
40
30
20
40.0
γ = 1.22
α = 5.0
FIGURE

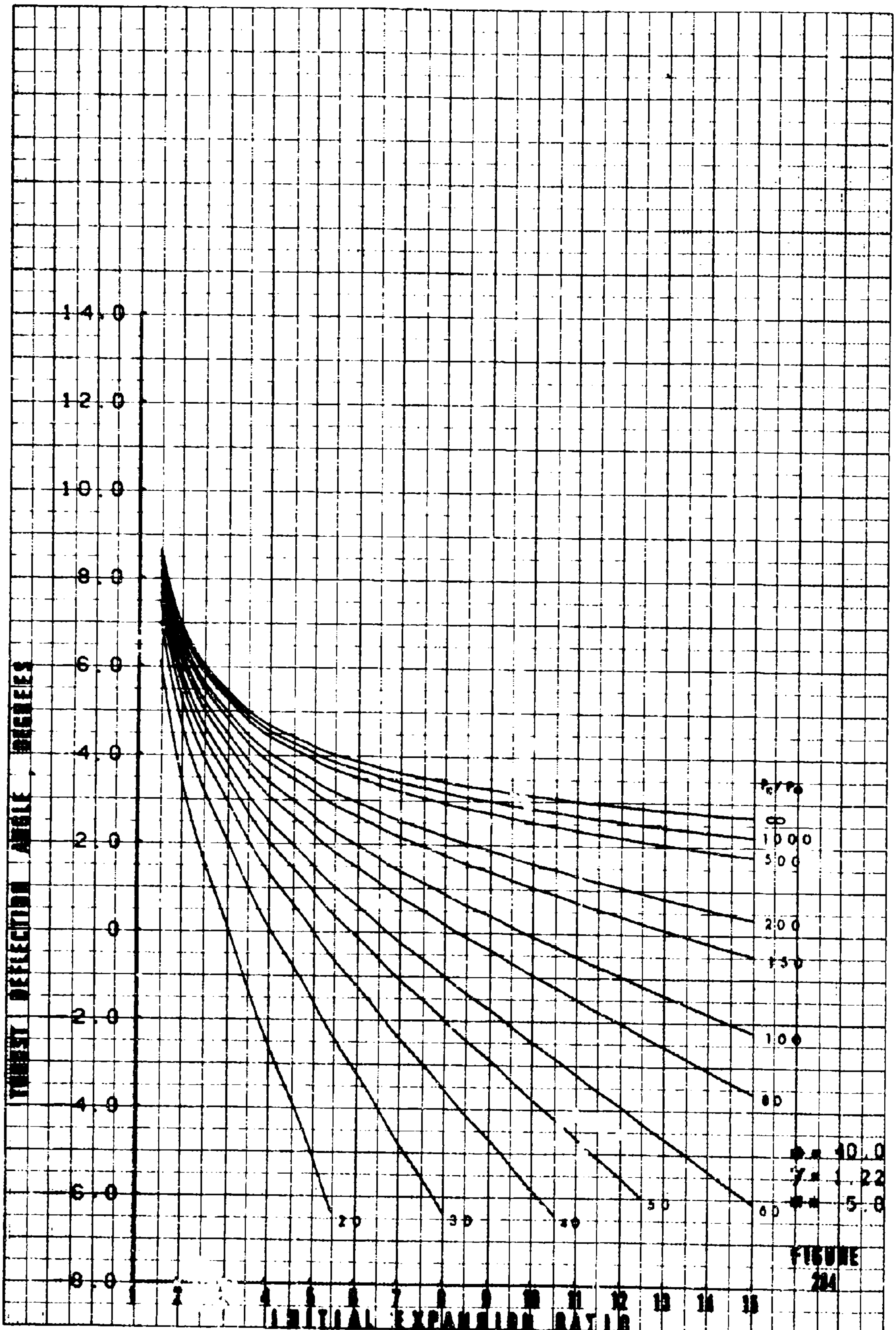
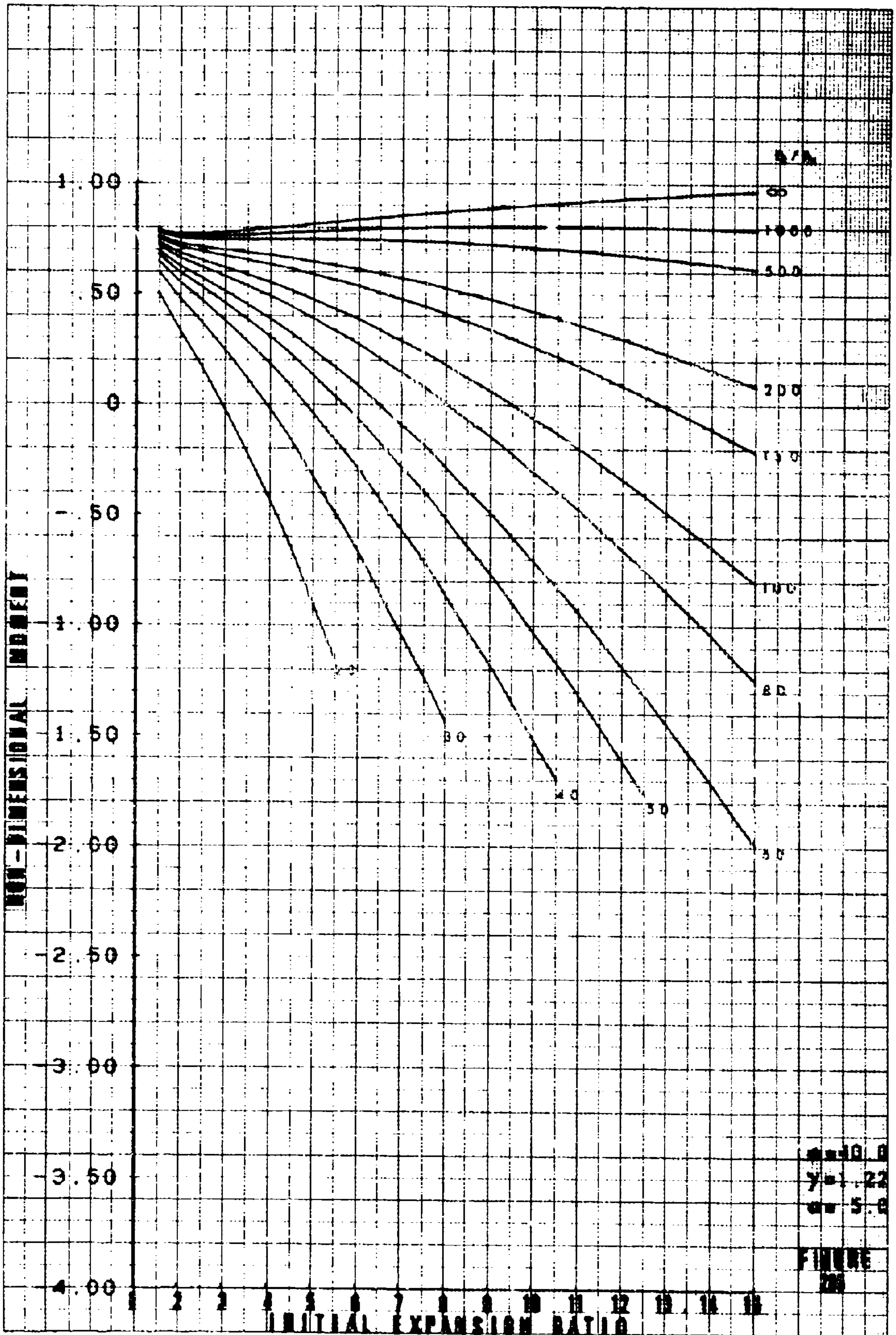
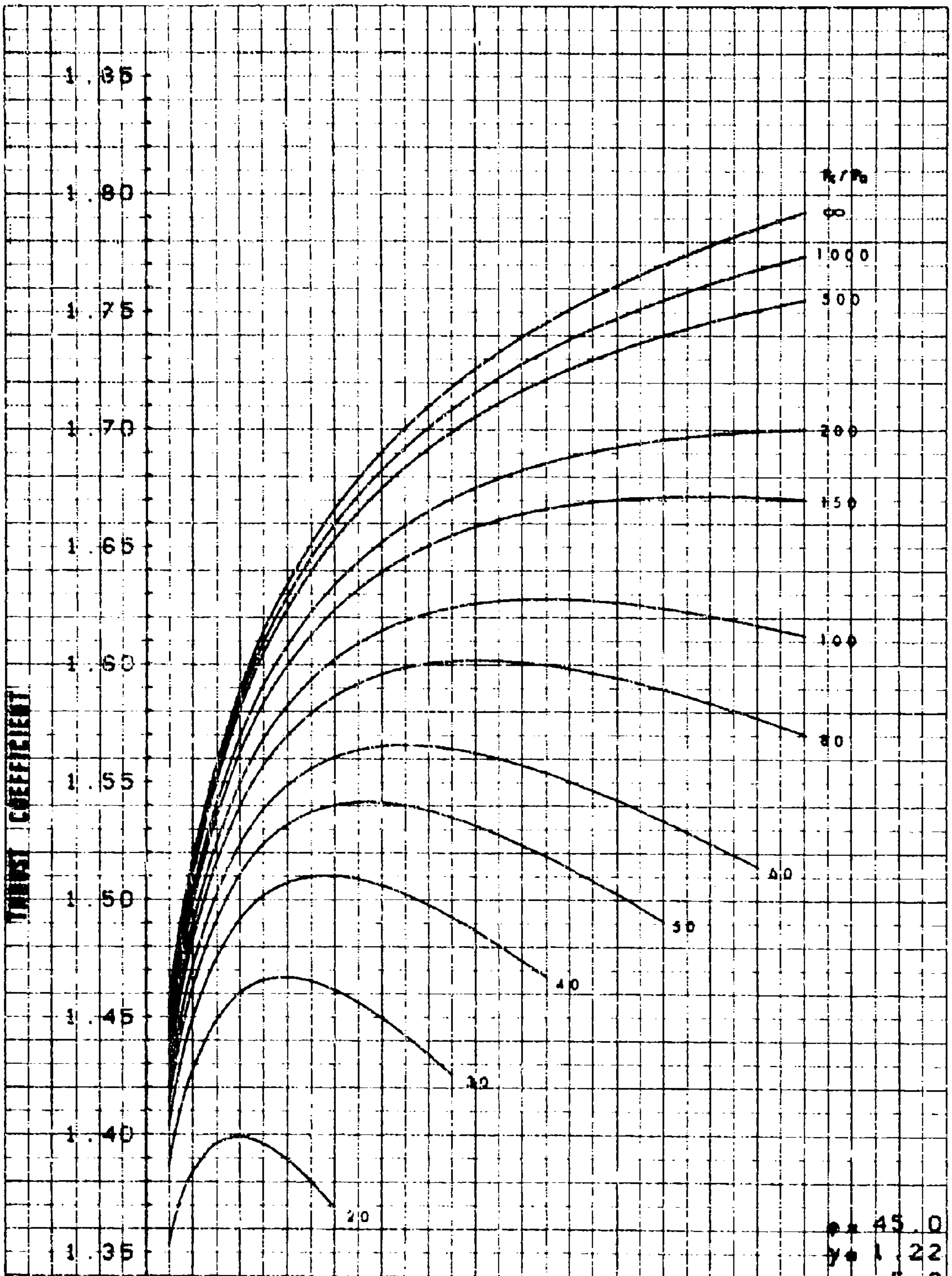
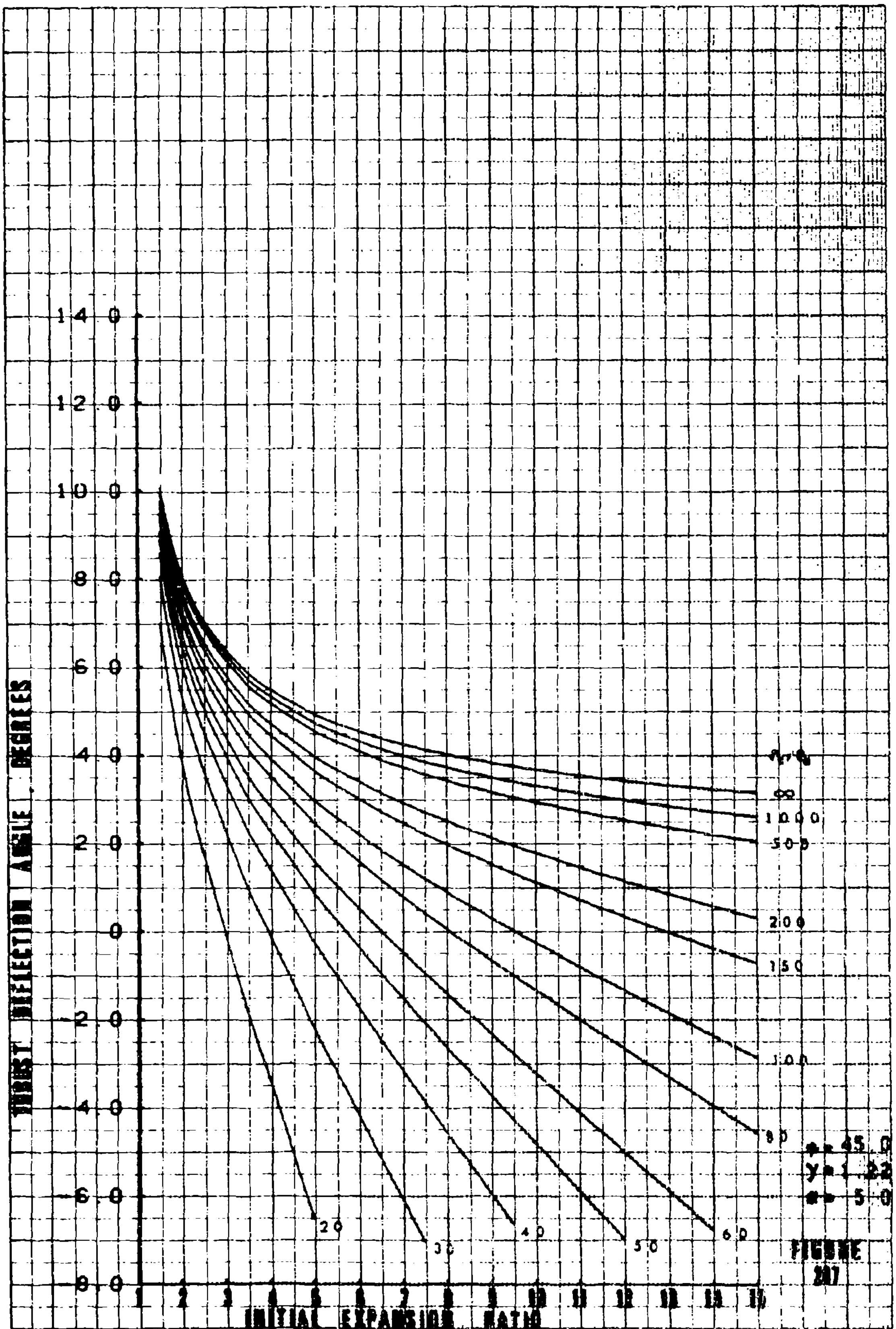

THRUST DEFLECTION ANGLE, DEGREES
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0
-2.0
-4.0
-6.0
-8.0
INITIAL EXPANSION RATIO
1
2
4
5
6
7
8
9
10
11
12
13
14
15
Pc/Pa
∞
1000
500
200
150
100
80
60
50
40
30
20
γ = 1.22
5.0

FIGURE 284

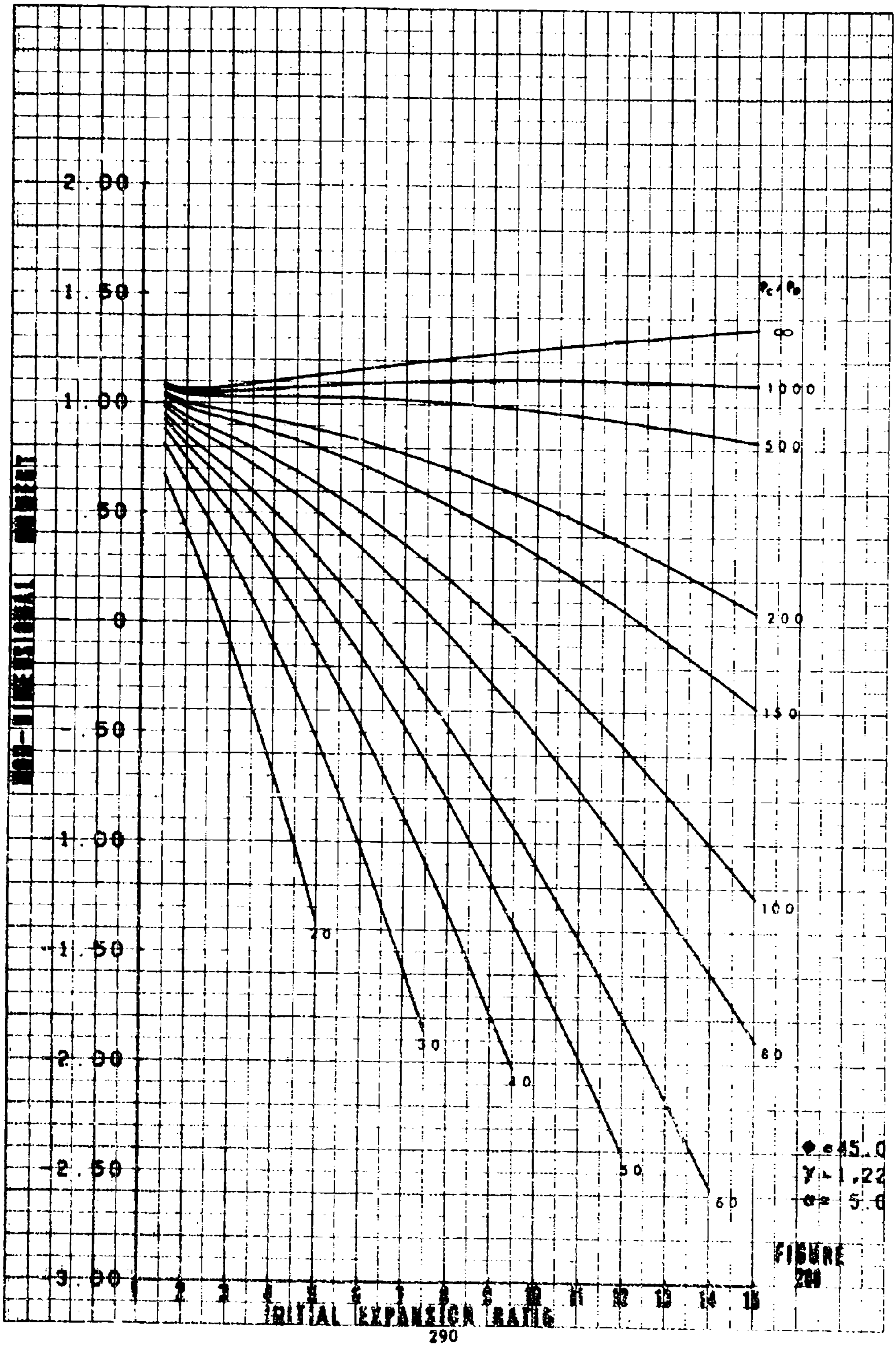


NON-DIMENSIONAL MOMENT
INITIAL EXPANSION RATIO
1.00
.50
0
-.50
-1.00
-1.50
-2.00
-2.50
-3.00
-3.50
-4.00
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
∞
1000
500
200
150
100
80
30
40
50
60


THRUST COEFFICIENT
INITIAL EXPANSION RATIO
P_c/P_a
∞
1000
500
200
150
100
80
60
50
40
30
20
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
α = 45.0
γ = 1.22
ε = 5.0
FIGURE 286



THRUST DEFLECTION ANGLE, DEGREES
INITIAL EXPANSION RATIO
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0
-2.0
-4.0
-6.0
-8.0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
∞
1000
500
200
150
100
80
60
50
40
30
20
45.0
1.22
5.0
FIGURE



NON-DIMENSIONAL MOMENT
INITIAL EXPANSION RATIO
2.00
1.50
1.00
.50
0
-.50
-1.00
-1.50
-2.00
-2.50
-3.00
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
P_c/P_b
∞
1000
500
200
150
100
80
60
50
40
30
20
Φ = 45.0
γ = 1.22

FIGURE 201

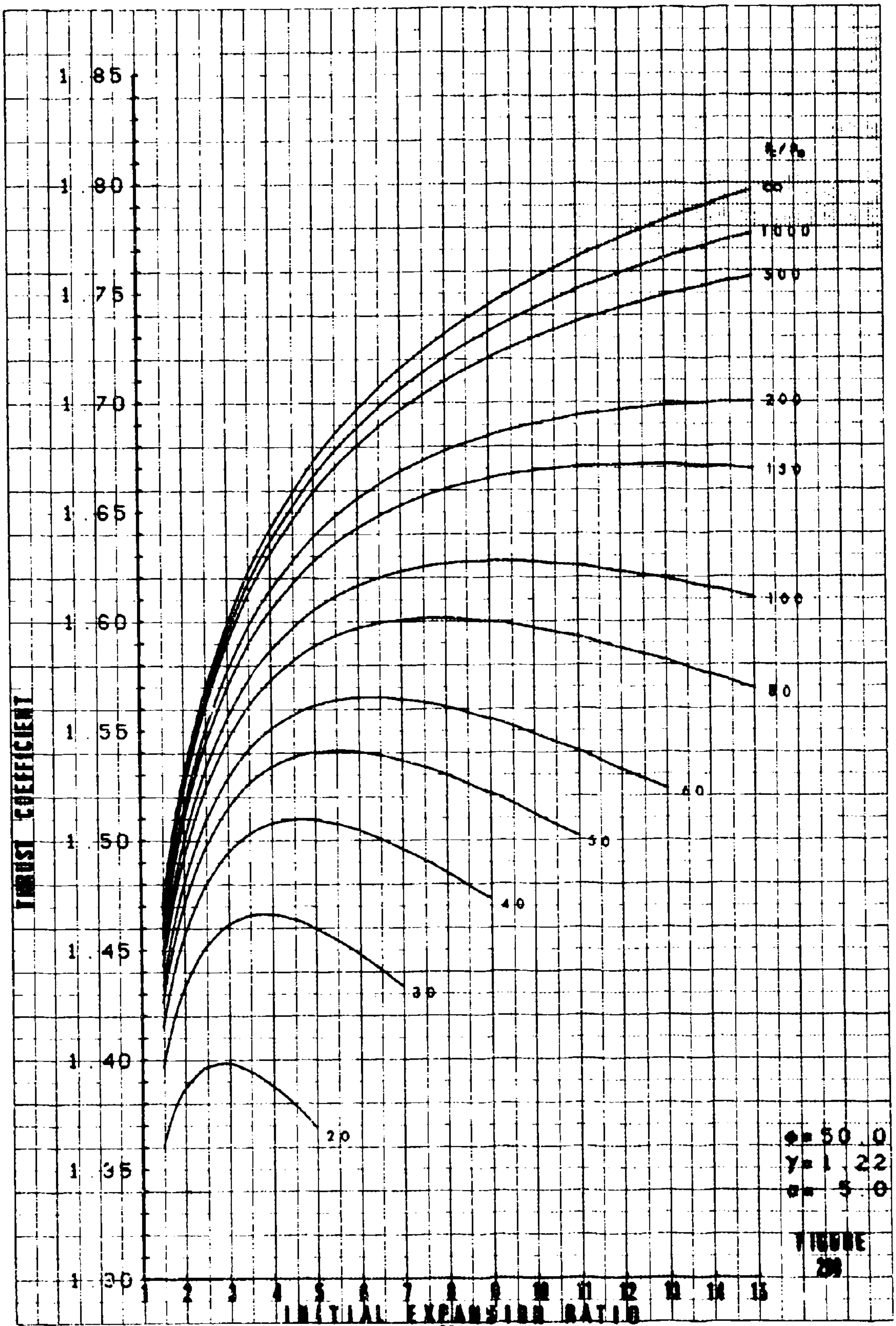
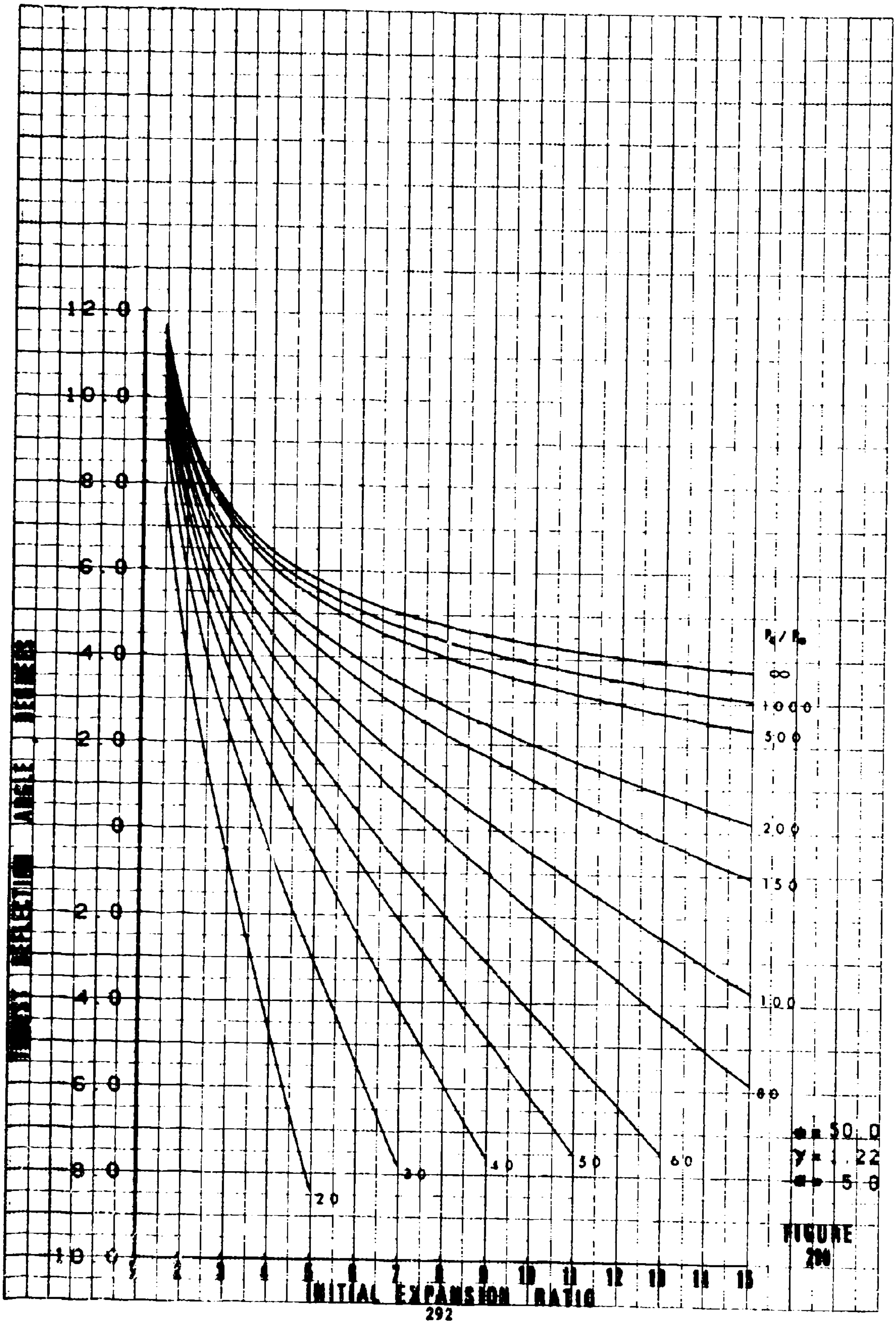
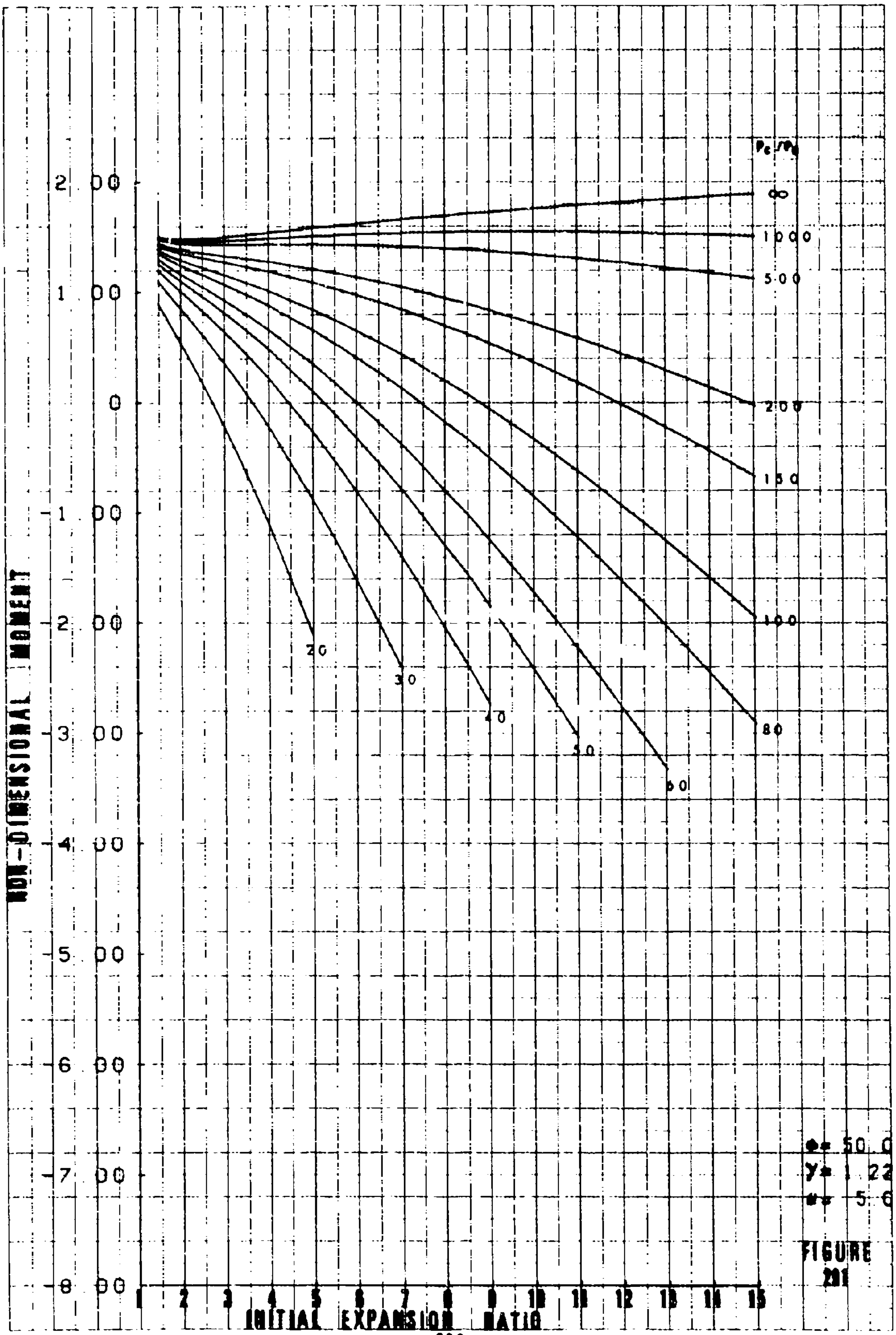

THRUST COEFFICIENT
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
P_c/P_a
∞
1000
500
200
150
100
80
60
50
40
30
20
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
ϕ = 50.0
γ = 1.22
α = 5.0

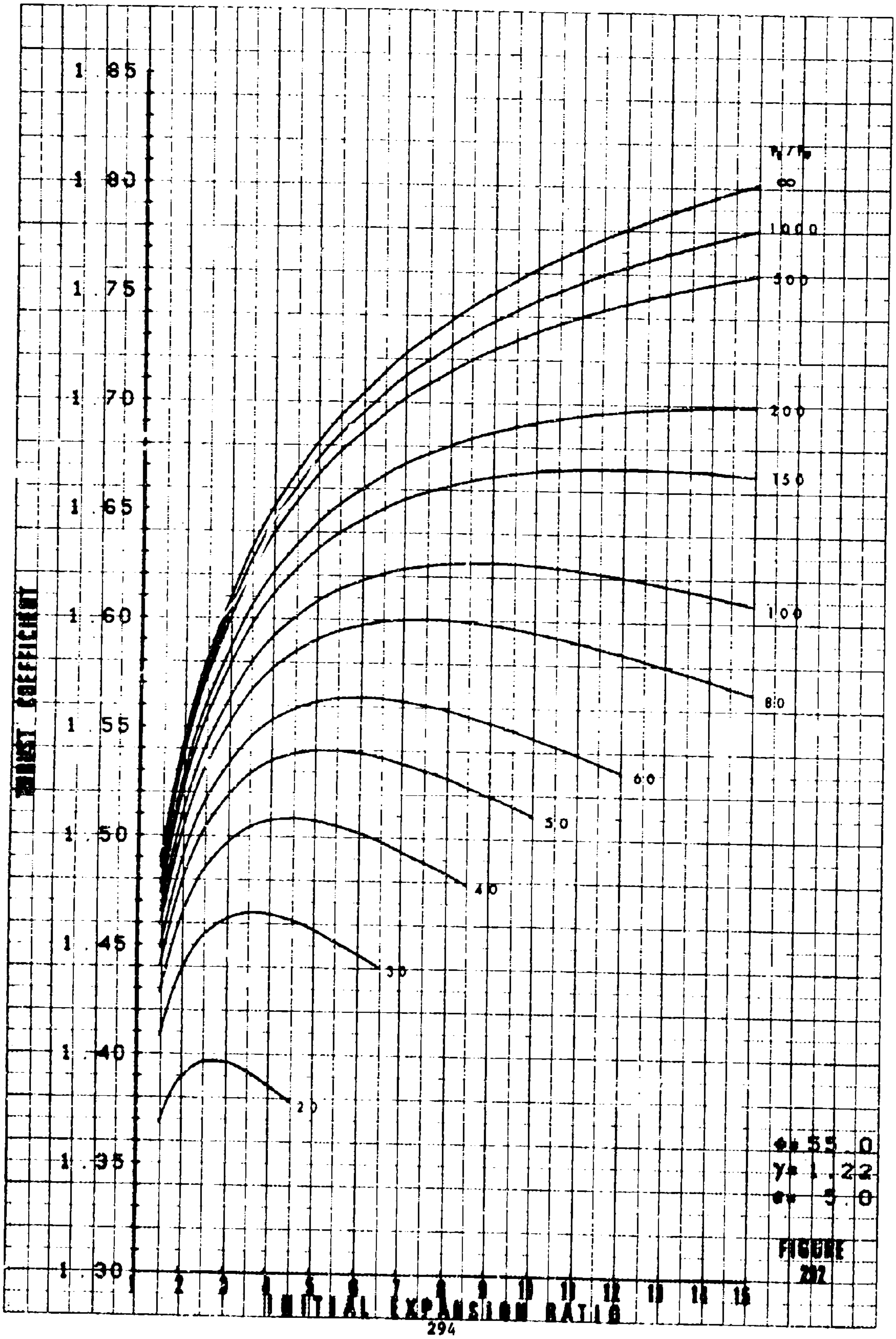
FIGURE
298

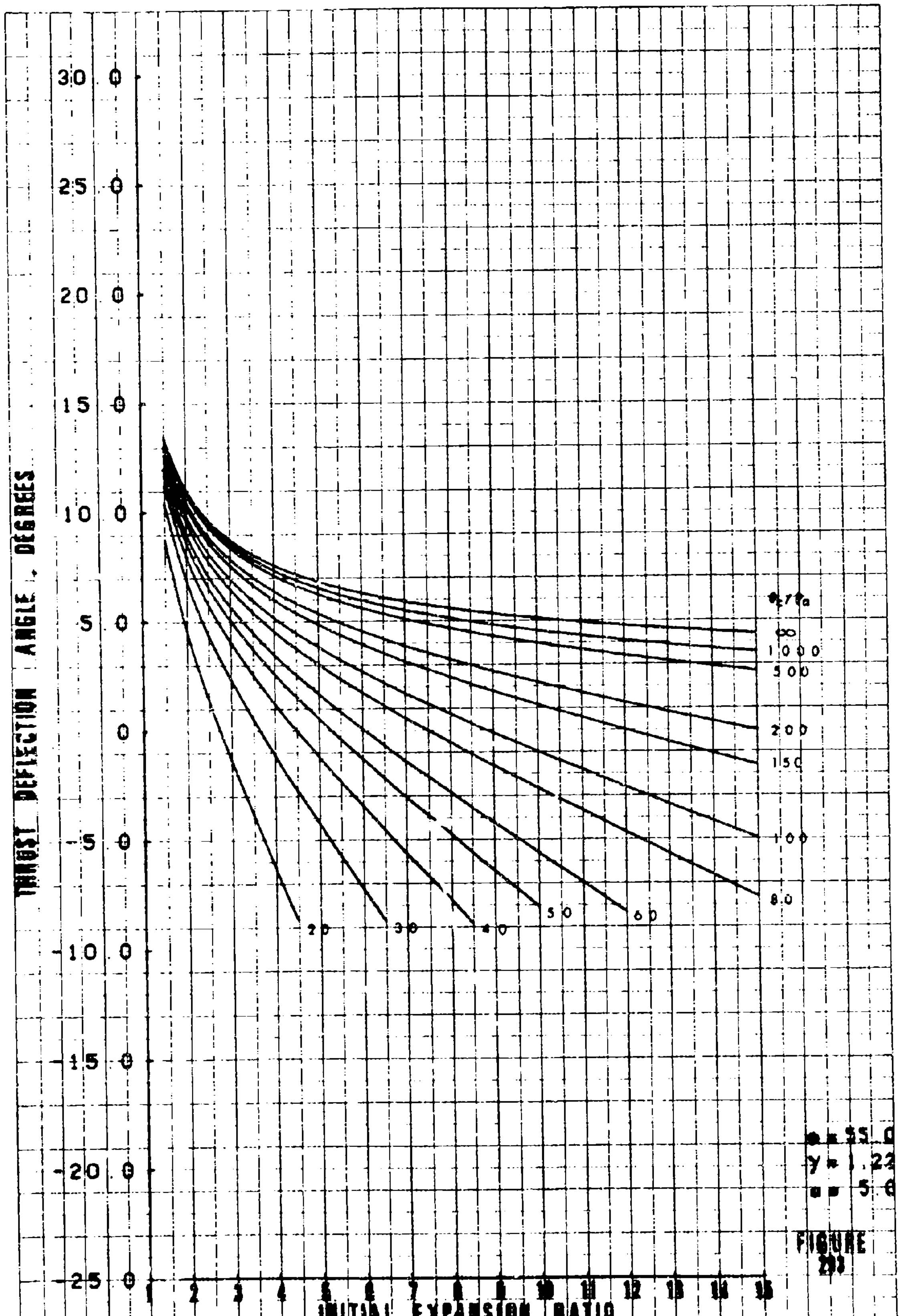


12.0
10.0
8.0
6.0
4.0
2.0
0
2.0
4.0
6.0
8.0
10.0
INITIAL EXPANSION RATIO
P_c / P_∞
∞
1000
500
200
150
100
80
60
50
40
30
20
50.0
.22
5.0
FIGURE 200

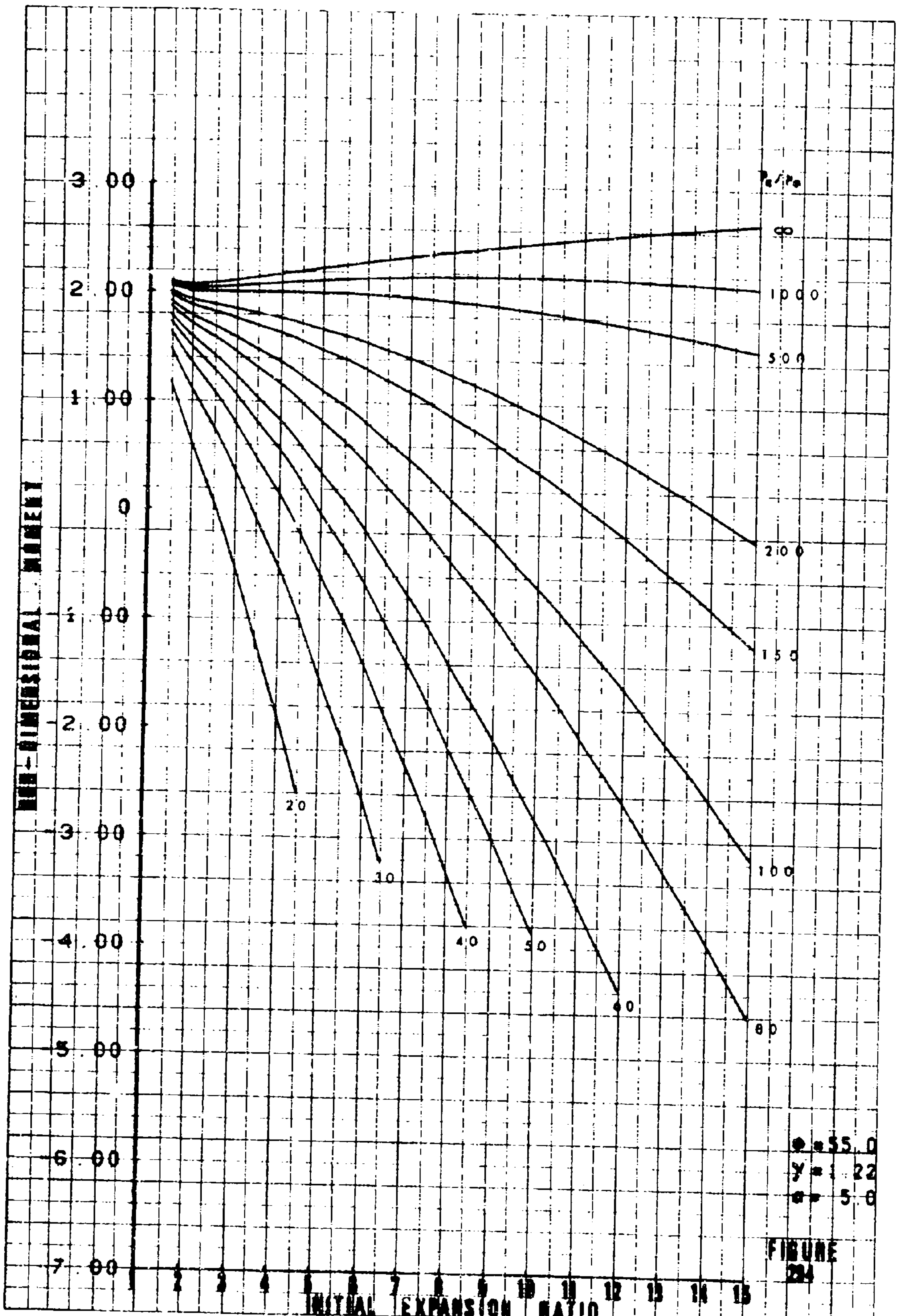


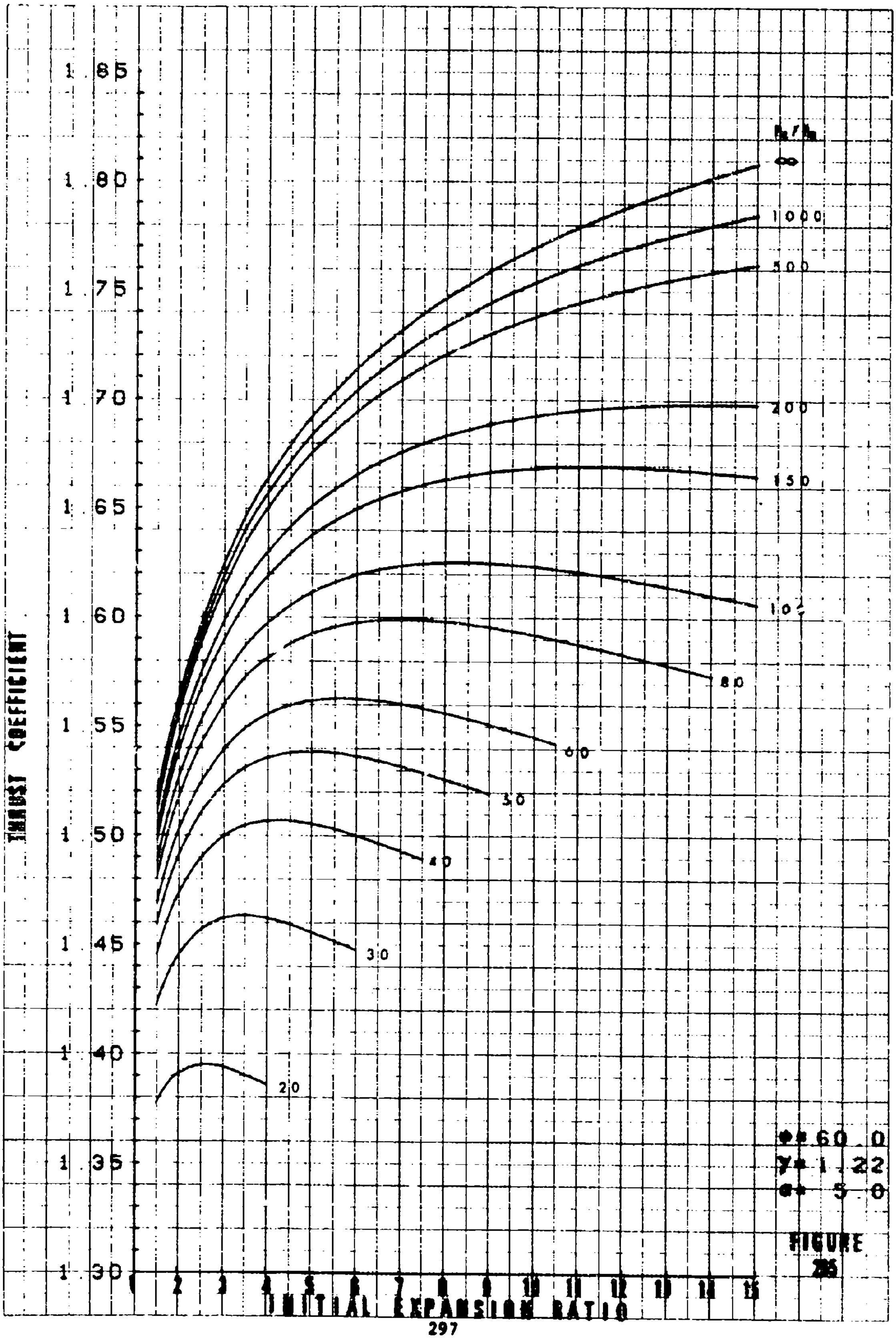
P_c/P_a
∞
1000
500
200
150
100
80
60
50
40
30
20
2.00
1.00
0
-1.00
-2.00
-3.00
-4.00
-5.00
-6.00
-7.00
-8.00
NON-DIMENSIONAL MOMENT
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO

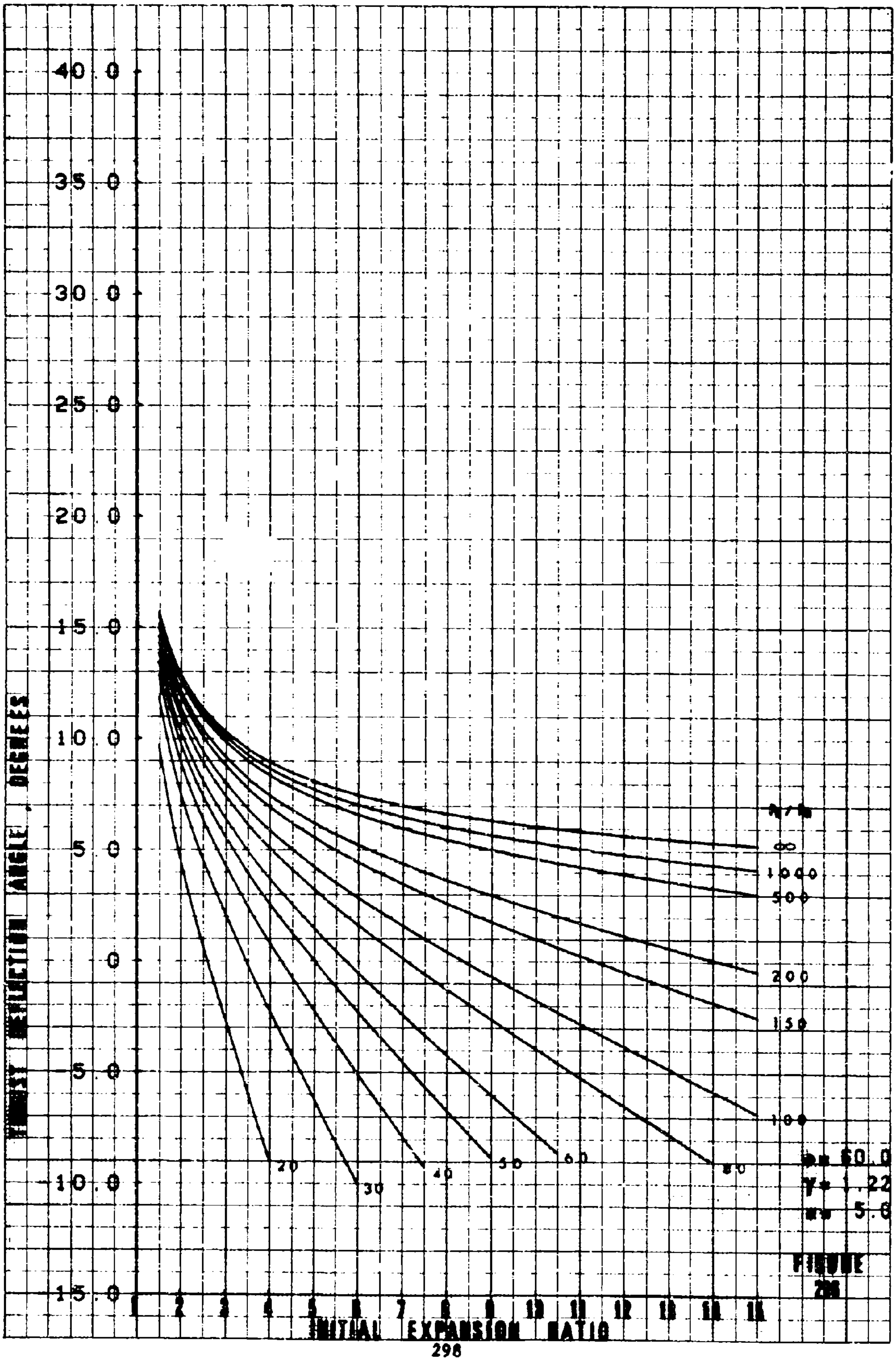

THRUST COEFFICIENT
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
INITIAL EXPANSION RATIO
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
P_1/P_a
∞
1000
500
200
150
100
80
60
50
40
30
20
φ= 55.0
γ= 1.22
ε= 5.0
FIGURE
292



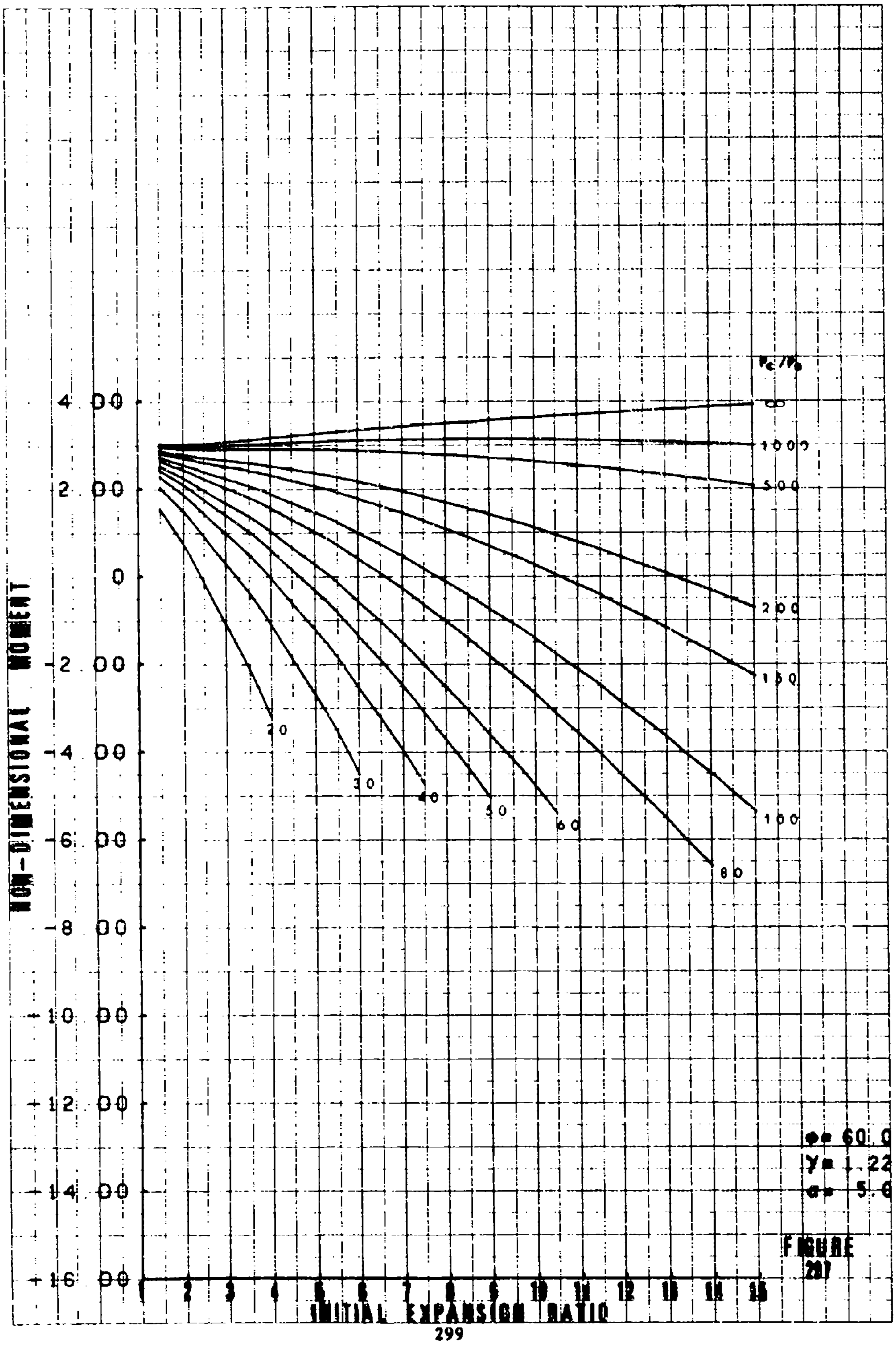
THRUST DEFLECTION ANGLE, DEGREES
30.0
25.0
20.0
15.0
10.0
5.0
0
-5.0
-10.0
-15.0
-20.0
-25.0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
INITIAL EXPANSION RATIO
∞
1000
500
200
150
100
8.0
6.0
5.0
4.0
3.0
2.0
FIGURE
293


NON-DIMENSIONAL MOMENT
INITIAL EXPANSION RATIO
P_c/P_a
∞
1000
500
200
150
100
80
60
50
40
30
20
3.00
2.00
1.00
0
-1.00
-2.00
-3.00
-4.00
-5.00
-6.00
-7.00
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
Φ = 55.0
γ = 1.22
α = 5.0
FIGURE 284

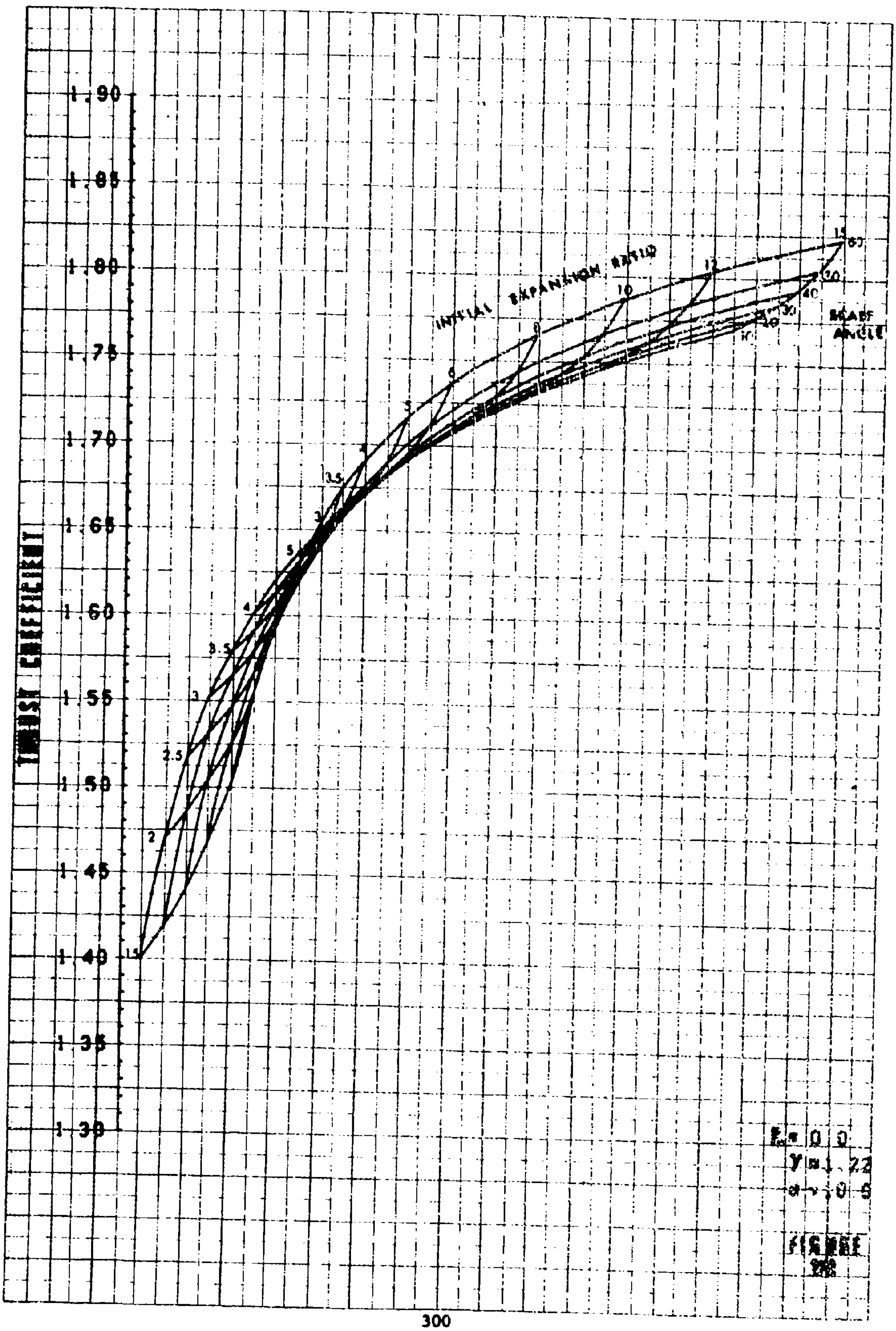

THRUST COEFFICIENT
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
INITIAL EXPANSION RATIO
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
∞
1000
500
200
150
100
80
60
50
40
30
20
Φ= 60.0
γ= 1.22
ε= 5.0
FIGURE
295



40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0
-5.0
-10.0
-15.0
ANGLE , DEGREES
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
INITIAL EXPANSION RATIO
∞
1000
500
200
150
100
80
60
50
40
30
20
1.22
5.6
FIGURE



NON-DIMENSIONAL MOMENT
INITIAL EXPANSION RATIO
P_c/P_a
∞
1000
500
200
150
100
80
60
50
40
30
20
φ= 60.0
γ= 1.22
α= 5.0
FIGURE 297


THRUST COEFFICIENT
1.90
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
INITIAL EXPANSION RATIO
SCARF ANGLE
E_n = 0.0
γ = 1.22
α = 0.5

FIGURE

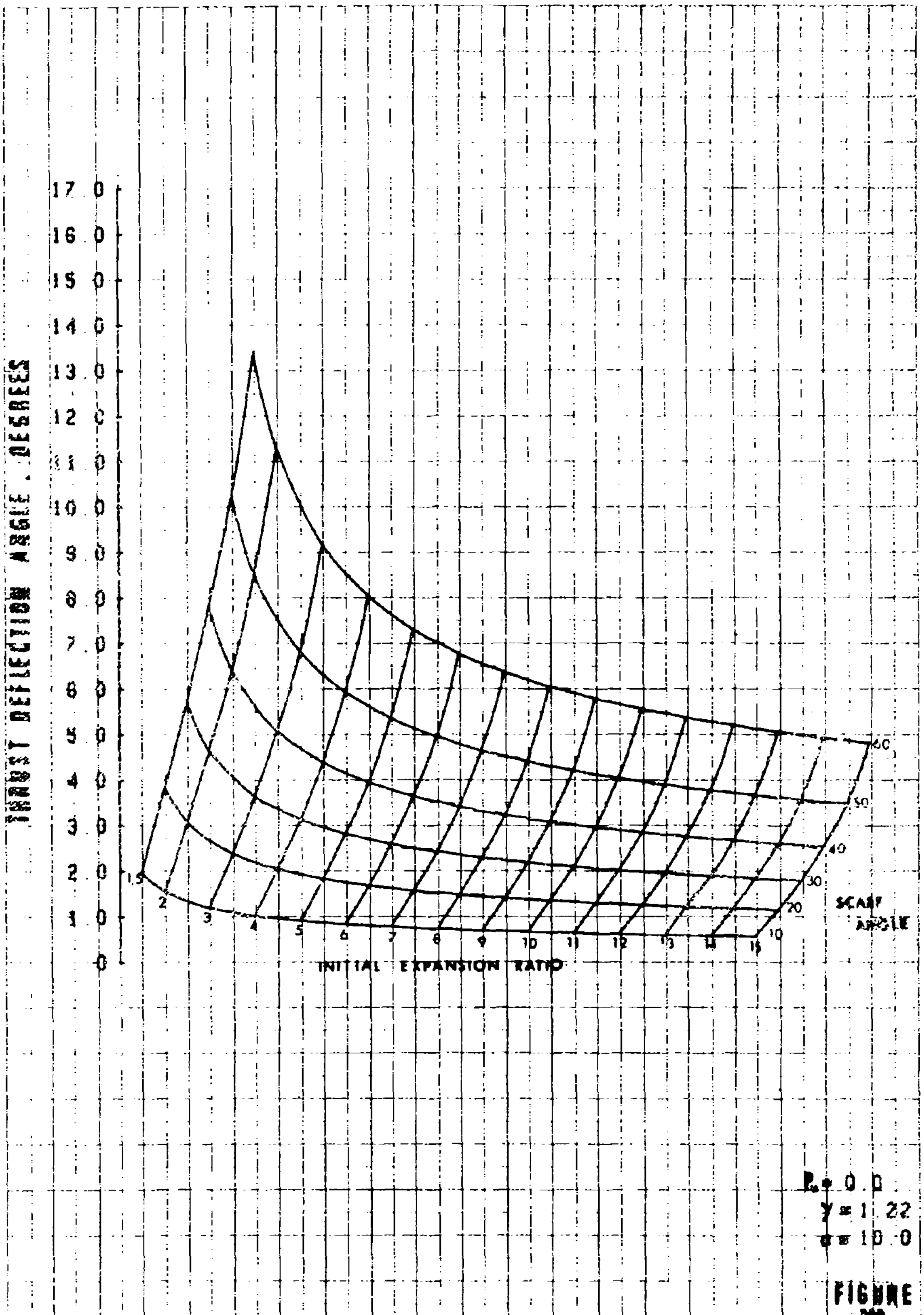
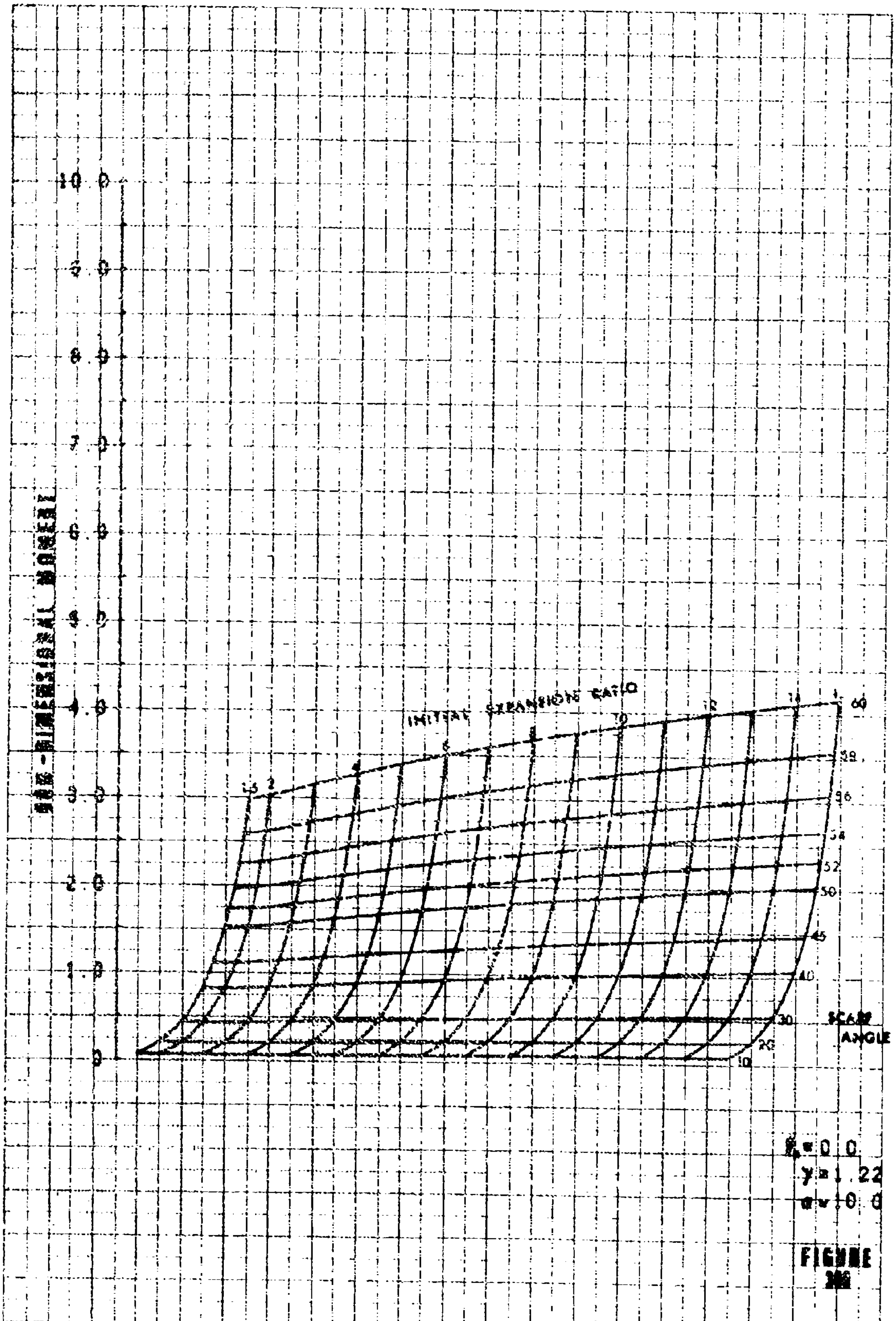

THRUST DEFLECTION ANGLE, DEGREES
INITIAL EXPANSION RATIO
SCARF ANGLE

FIGURE 200


NON-DIMENSIONAL MOMENT
INITIAL EXPANSION RATIO
SCARF ANGLE
γ = 1.22
FIGURE

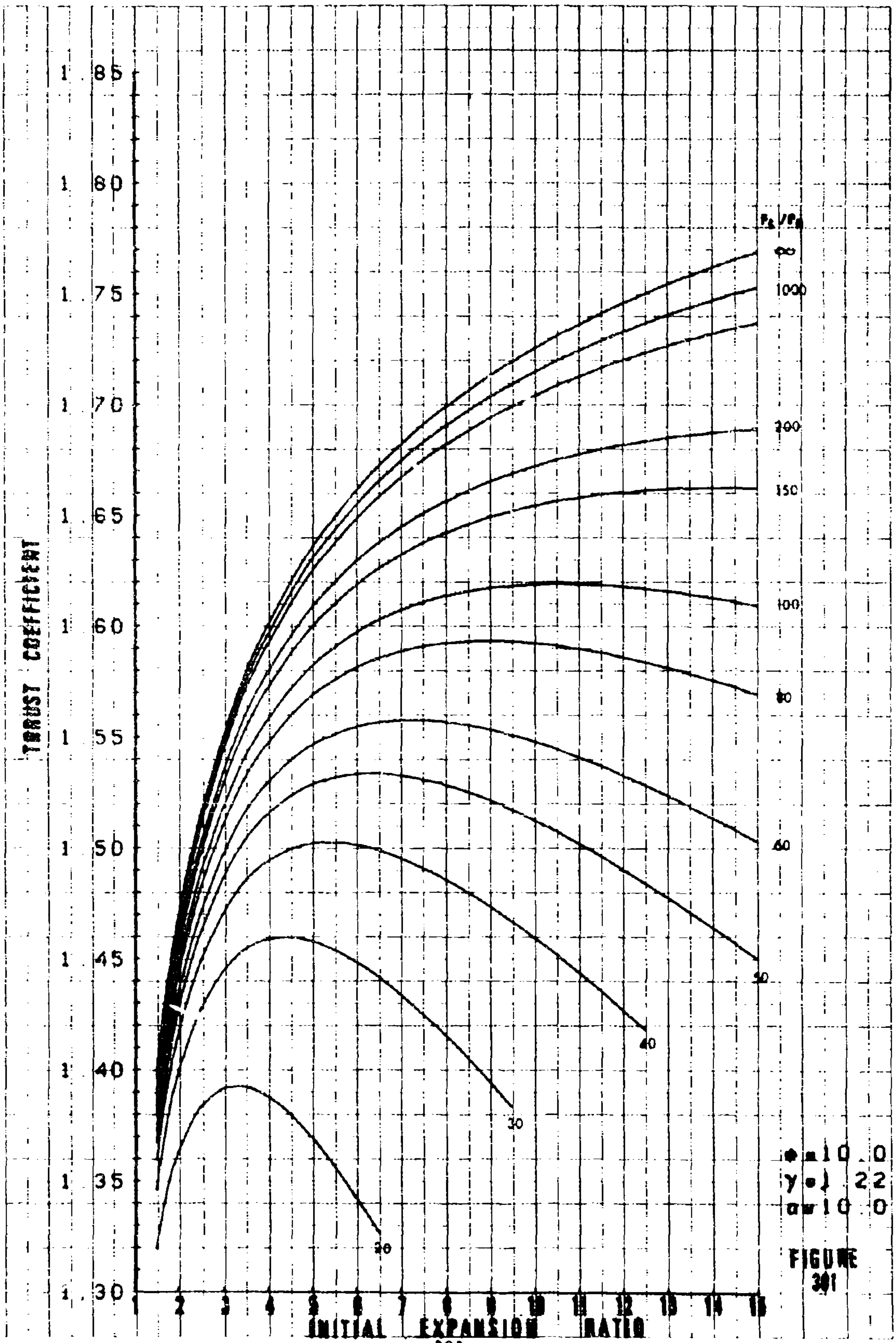

THRUST COEFFICIENT
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
∞
1000
200
150
100
80
60
50
40
30
20

FIGURE 301

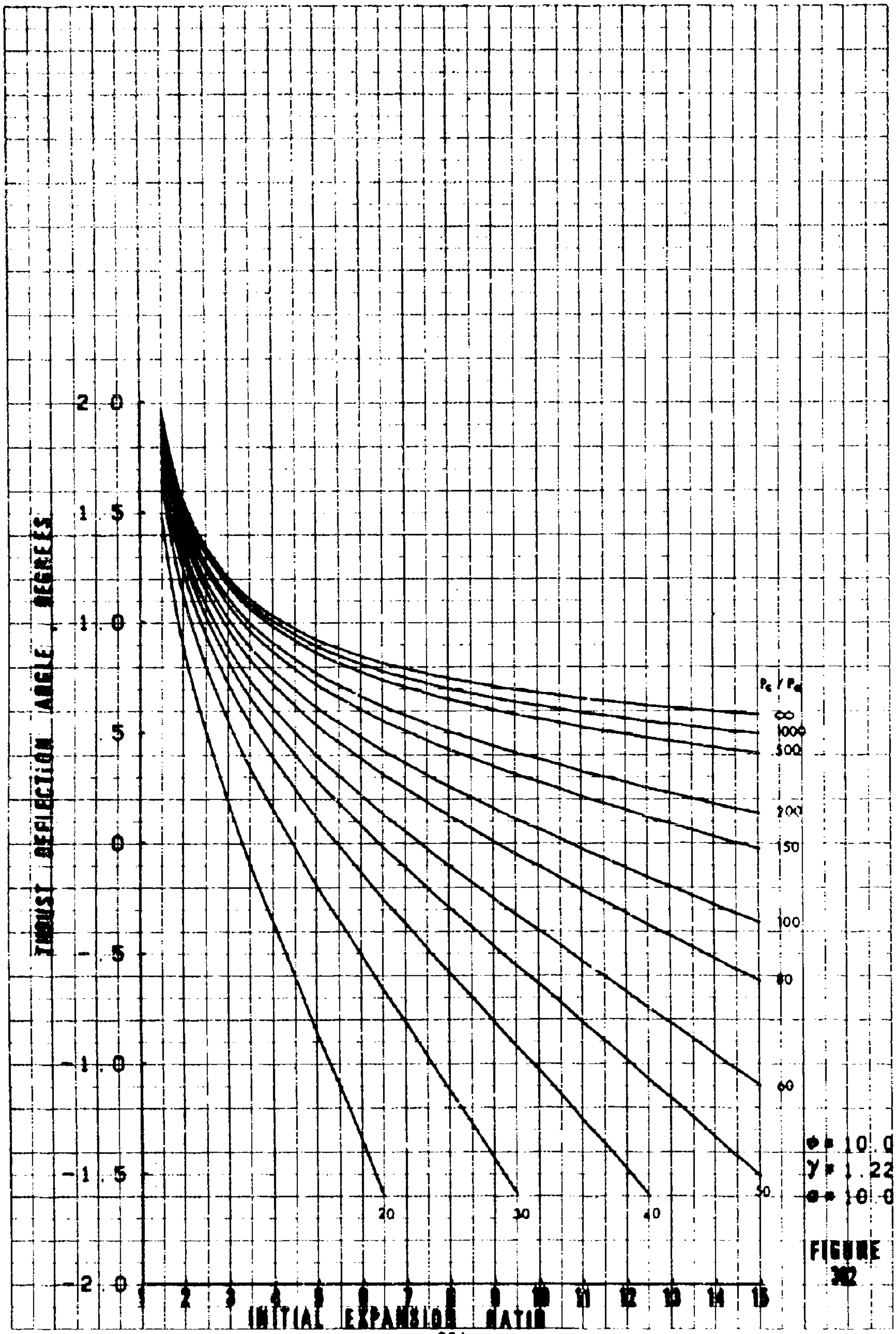
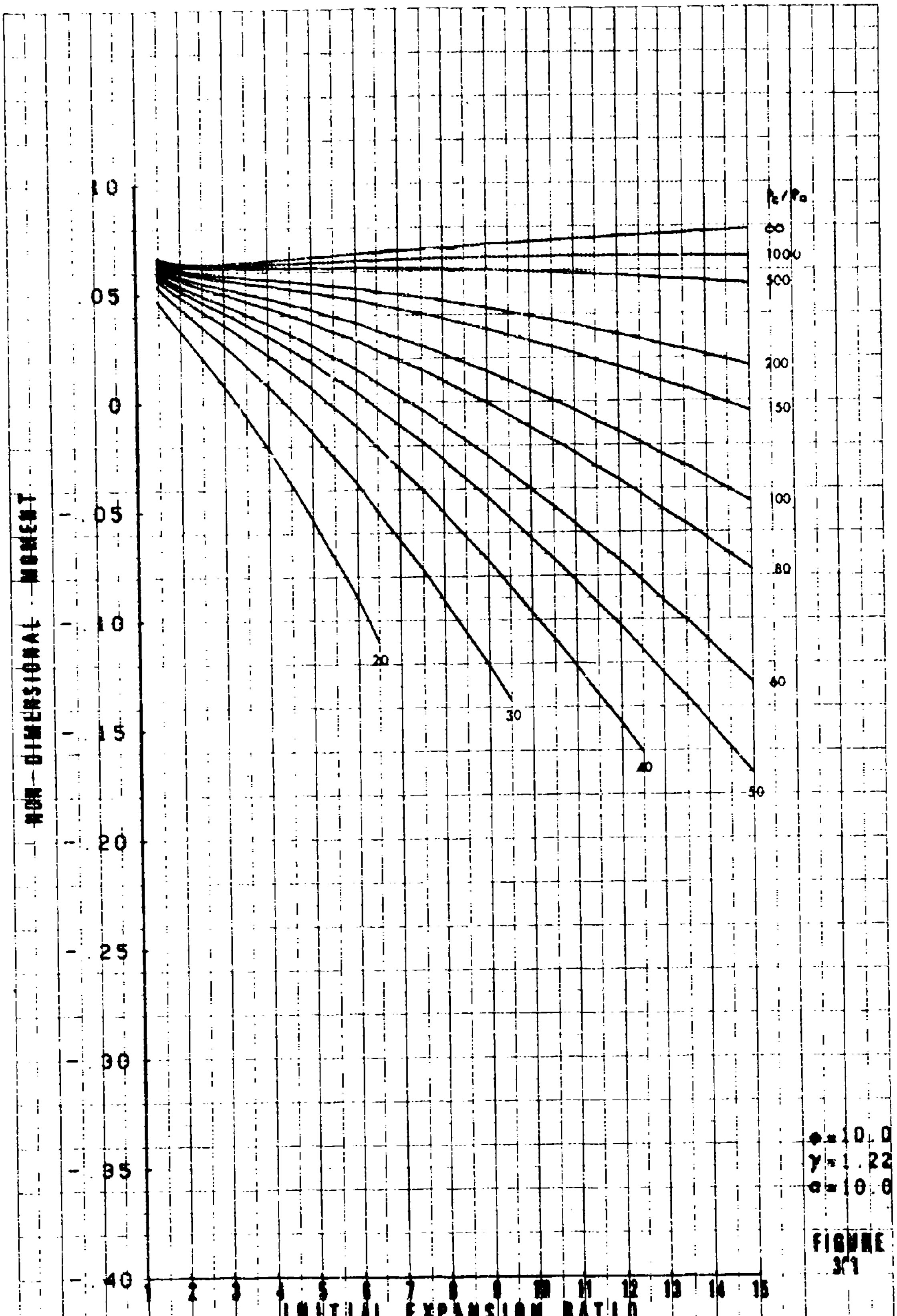
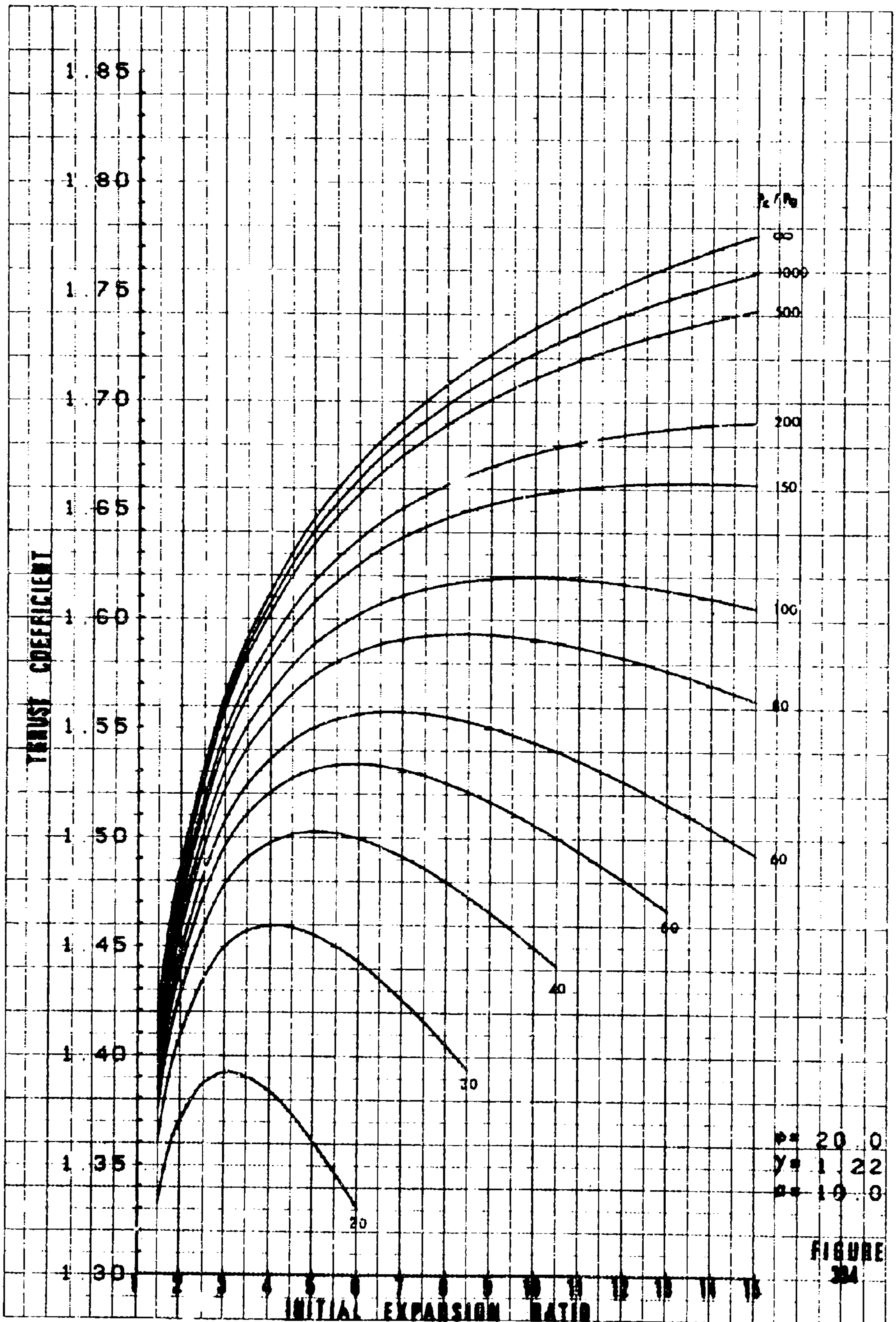

THRUST DEFLECTION ANGLE, DEGREES
2.0
1.5
1.0
.5
0
-.5
-1.0
-1.5
-2.0
INITIAL EXPANSION RATIO
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
P_c / P_a
∞
1000
500
200
150
100
80
60
50
40
30
20
ϕ = 10.0
γ = 1.22
θ = 10.0

FIGURE 302



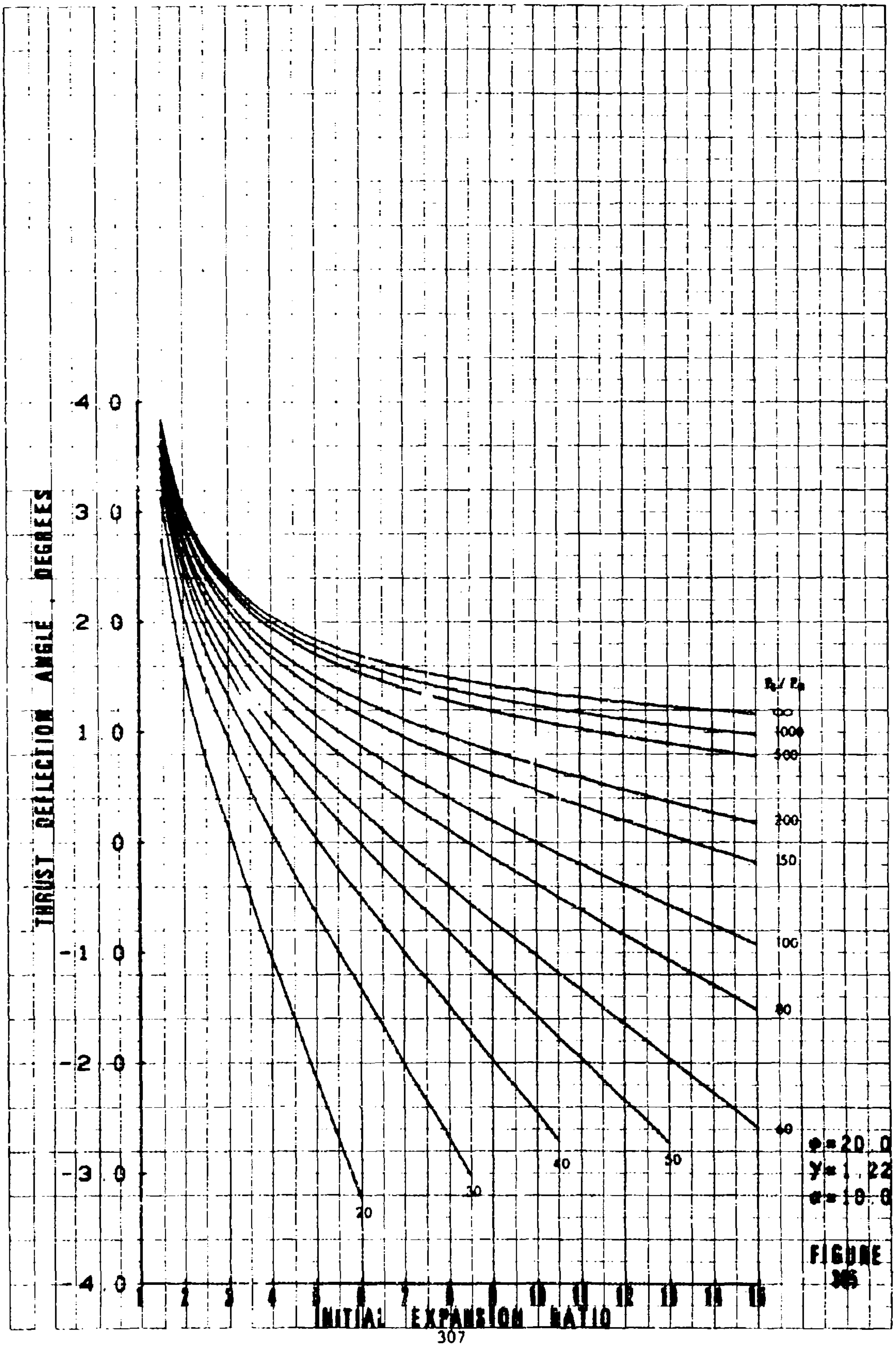
NON-DIMENSIONAL MOMENT
INITIAL EXPANSION RATIO
.10
.05
0
-.05
-.10
-.15
-.20
-.25
-.30
-.35
-.40
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
P_c/P_a
∞
1000
500
200
150
100
80
60
50
40
30
20
$\phi = 10.0$
$\gamma = 1.22$
$\alpha = 10.0$

FIGURE 3.1

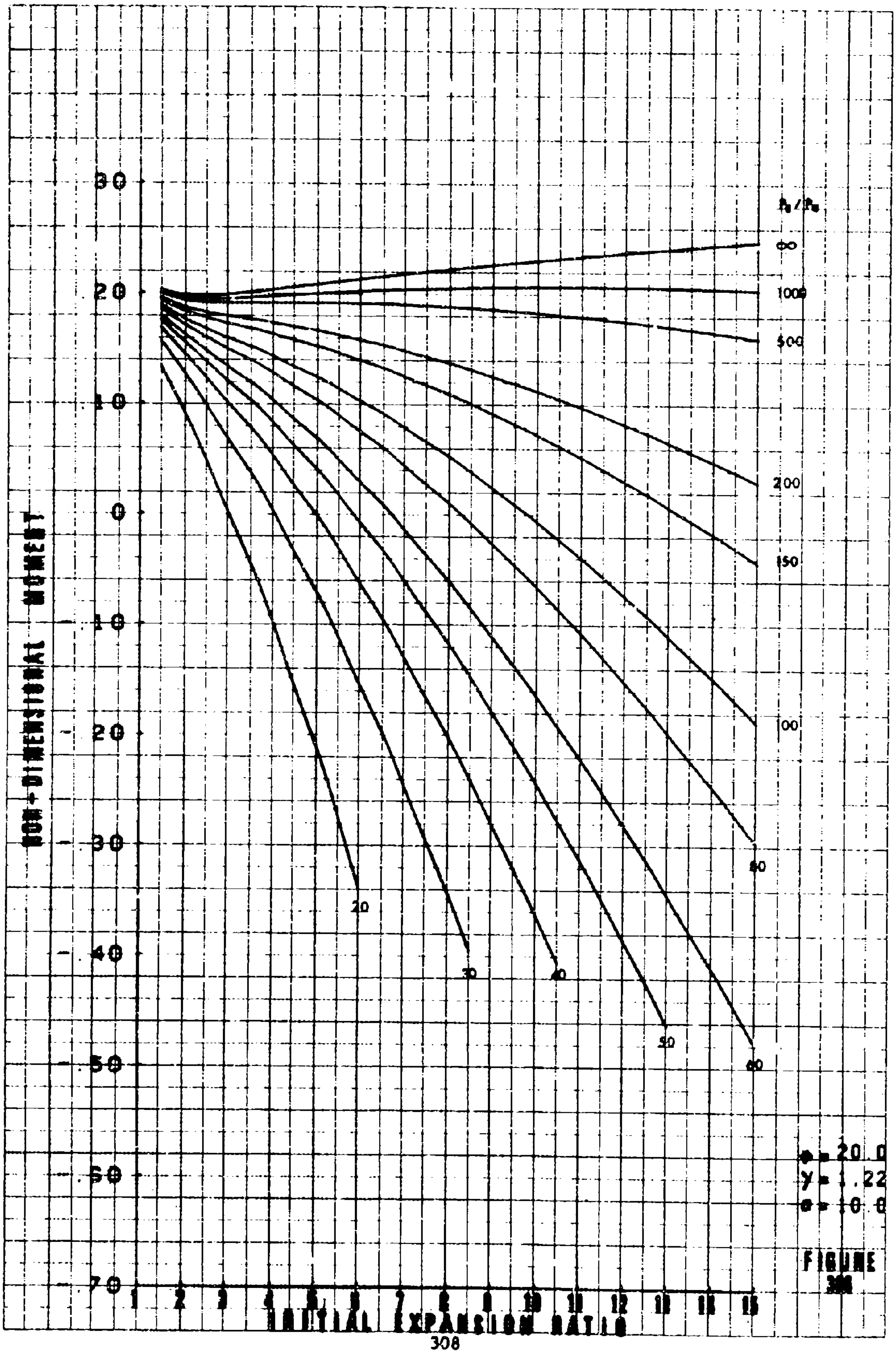


THRUST COEFFICIENT
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
INITIAL EXPANSION RATIO
P_c/P_a
∞
1000
500
200
150
100
80
60
60
40
30
20
γ = 1.22

FIGURE 304



THRUST DEFLECTION ANGLE, DEGREES
4.0
3.0
2.0
1.0
0
-1.0
-2.0
-3.0
-4.0
INITIAL EXPANSION RATIO
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
∞
1000
500
200
150
100
80
60
50
40
30
20
φ = 20.0
γ = 1.22
FIGURE


NON-DIMENSIONAL MOMENT
INITIAL EXPANSION RATIO
P_0/P_a
∞
1000
500
200
150
100
80
20
30
40
50
60
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
FIGURE

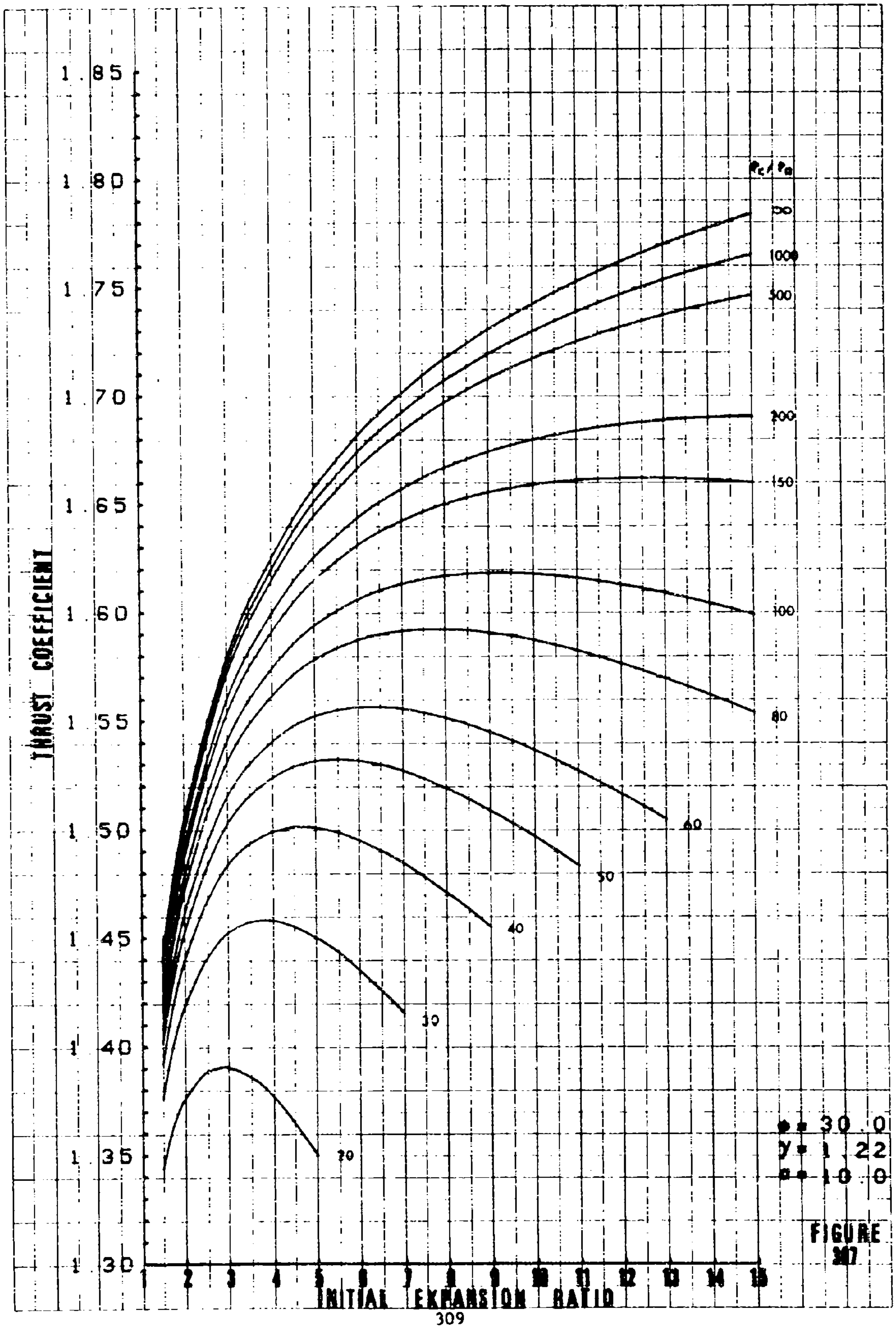
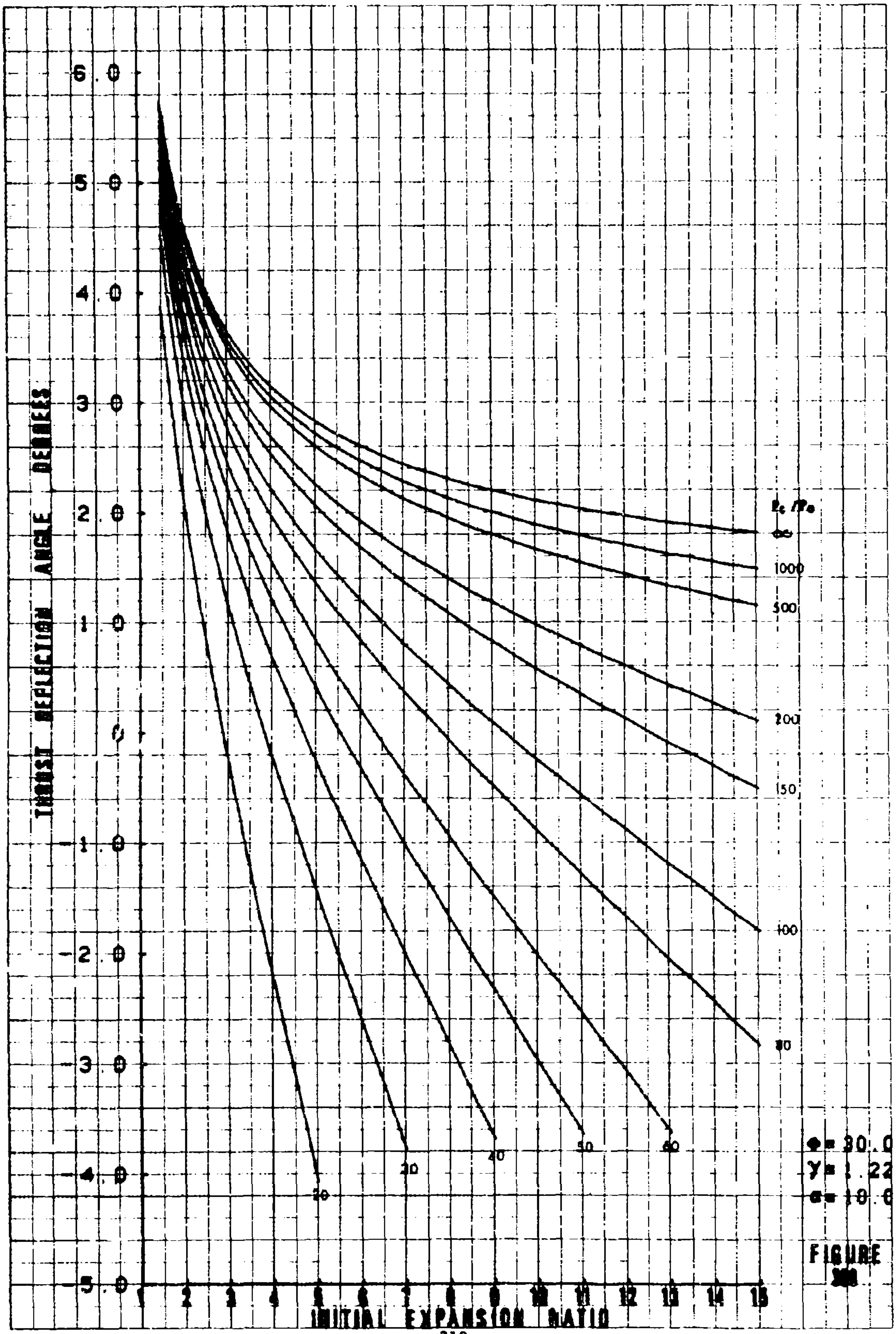
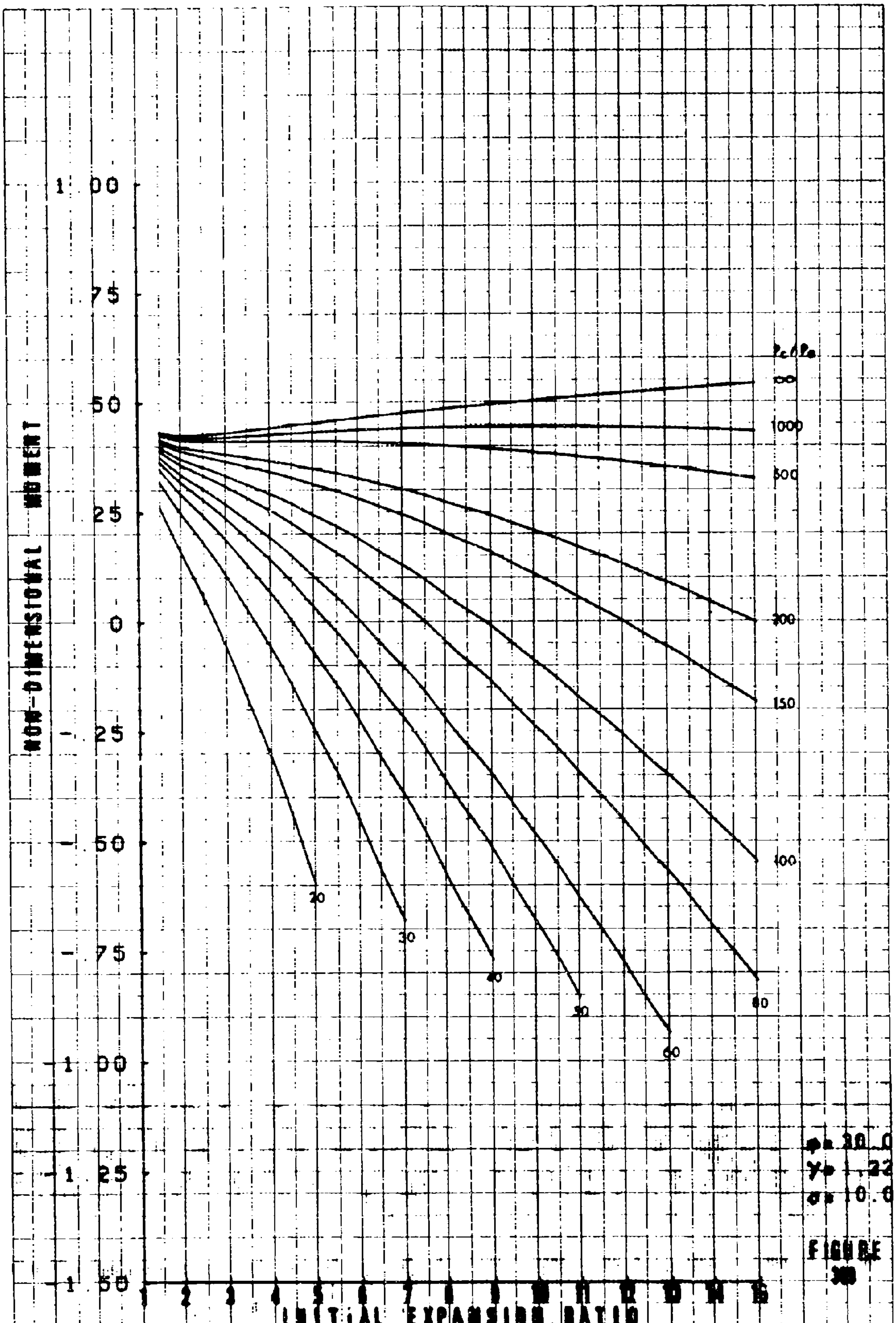
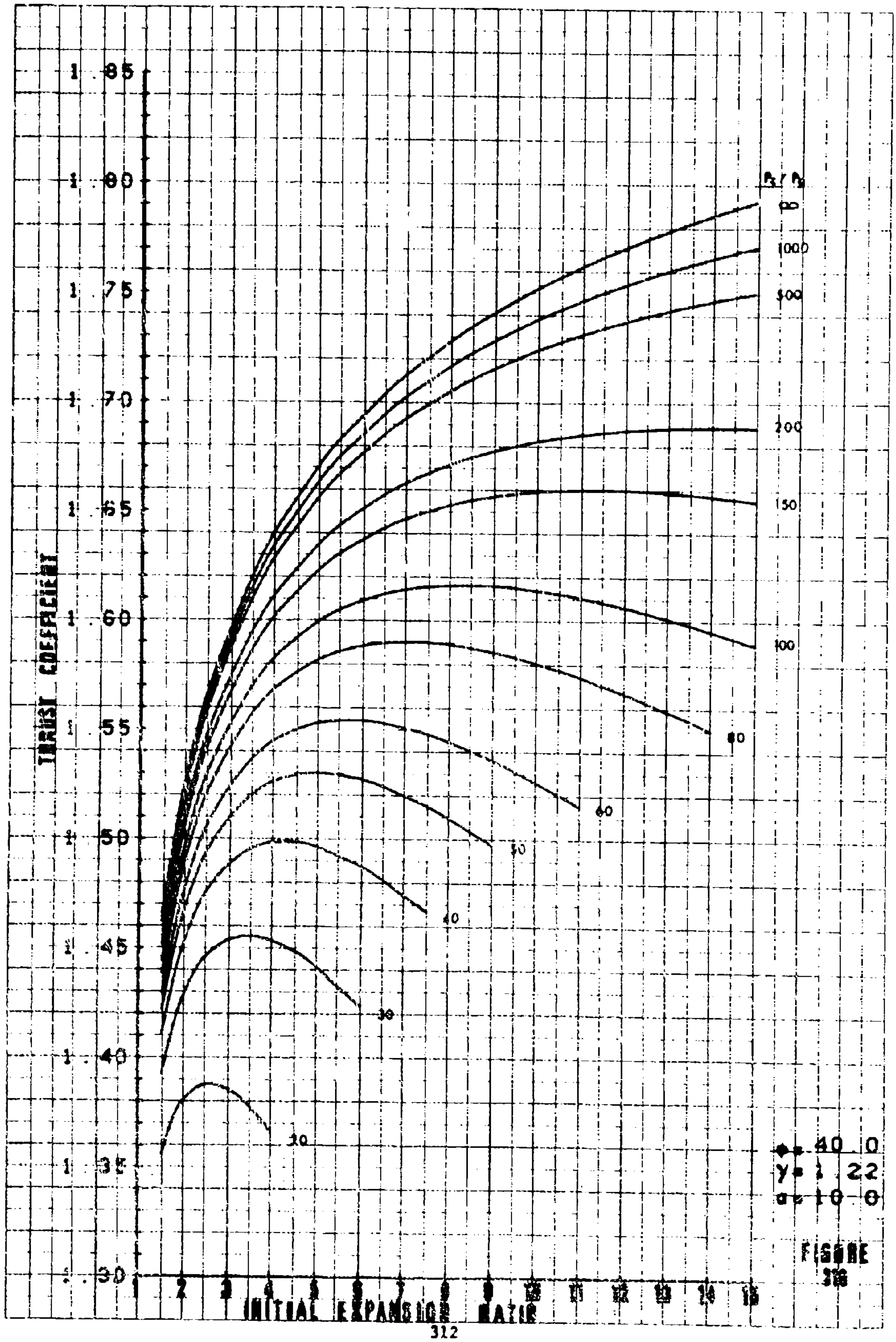

THRUST COEFFICIENT
INITIAL EXPANSION RATIO
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
P_c/P_a
∞
1000
500
200
150
100
80
60
50
40
30
20
1.22
10.0

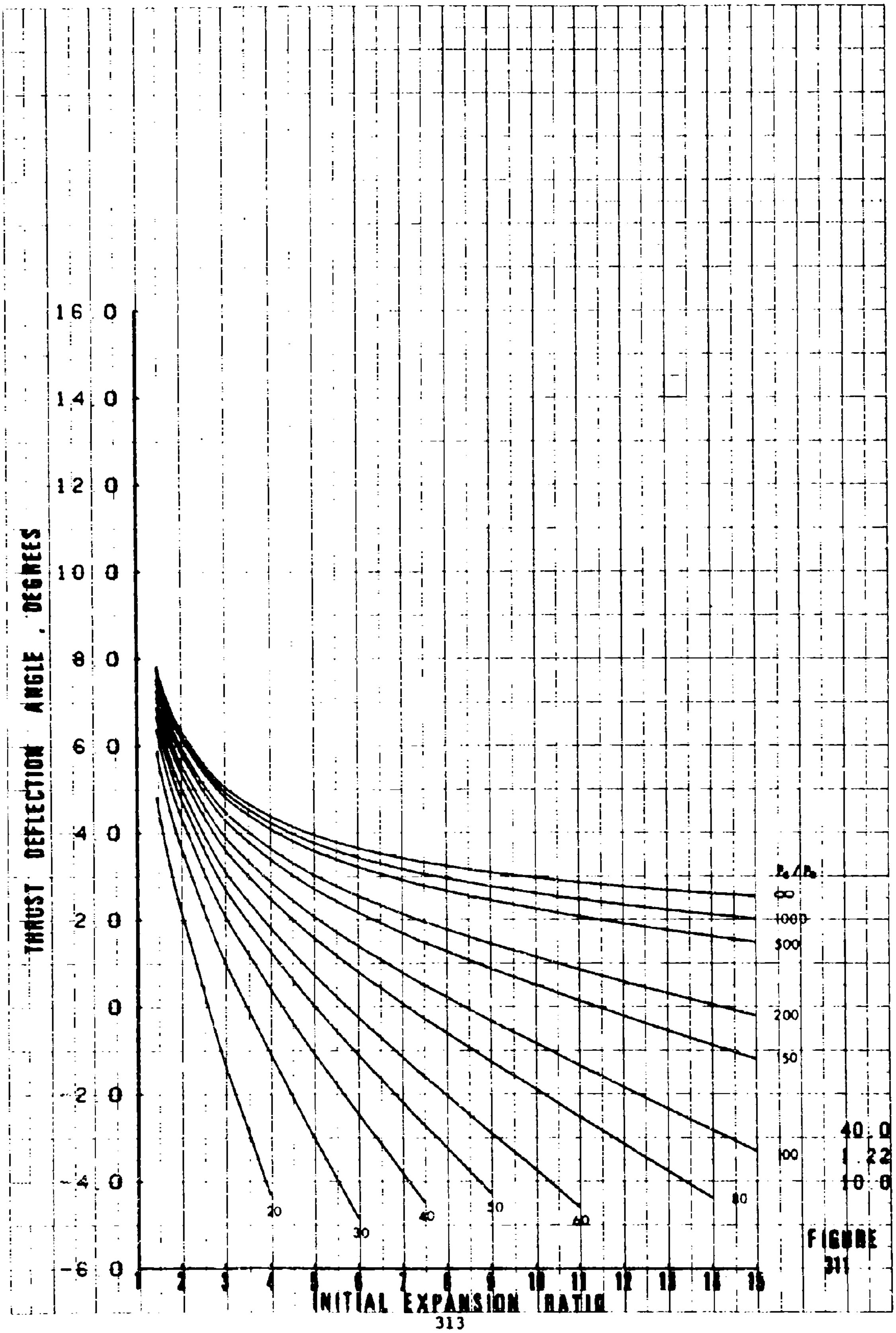
FIGURE 3?7


THRUST DEFLECTION ANGLE DEGREES
6.0
5.0
4.0
3.0
2.0
1.0
0
-1.0
-2.0
-3.0
-4.0
-5.0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
Pc/Pa
∞
1000
500
200
150
100
80
20
30
40
50
60
φ= 30.0
γ= 1.22
σ= 10.0

FIGURE


NON-DIMENSIONAL MOMENT
1.00
.75
.50
.25
0
-.25
-.50
-.75
-1.00
-1.25
-1.50
INITIAL EXPANSION RATIO
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
P_c/P_a
∞
1000
500
200
150
100
80
60
50
40
30
20
0.0
10.0
FIGURE


1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
THRUST COEFFICIENT
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
INITIAL EXPANSION RATIO
Pc / Pa
∞
1000
500
200
150
100
80
60
50
40
30
20
φ = 40.0
γ = 1.22
α = 10.0
FIGURE
316



THRUST DEFLECTION ANGLE, DEGREES
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0
-2.0
-4.0
-6.0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
INITIAL EXPANSION RATIO
20
30
40
50
60
80
100
150
200
500
1000
∞
40.0
1.22
10.0
FIGURE 311

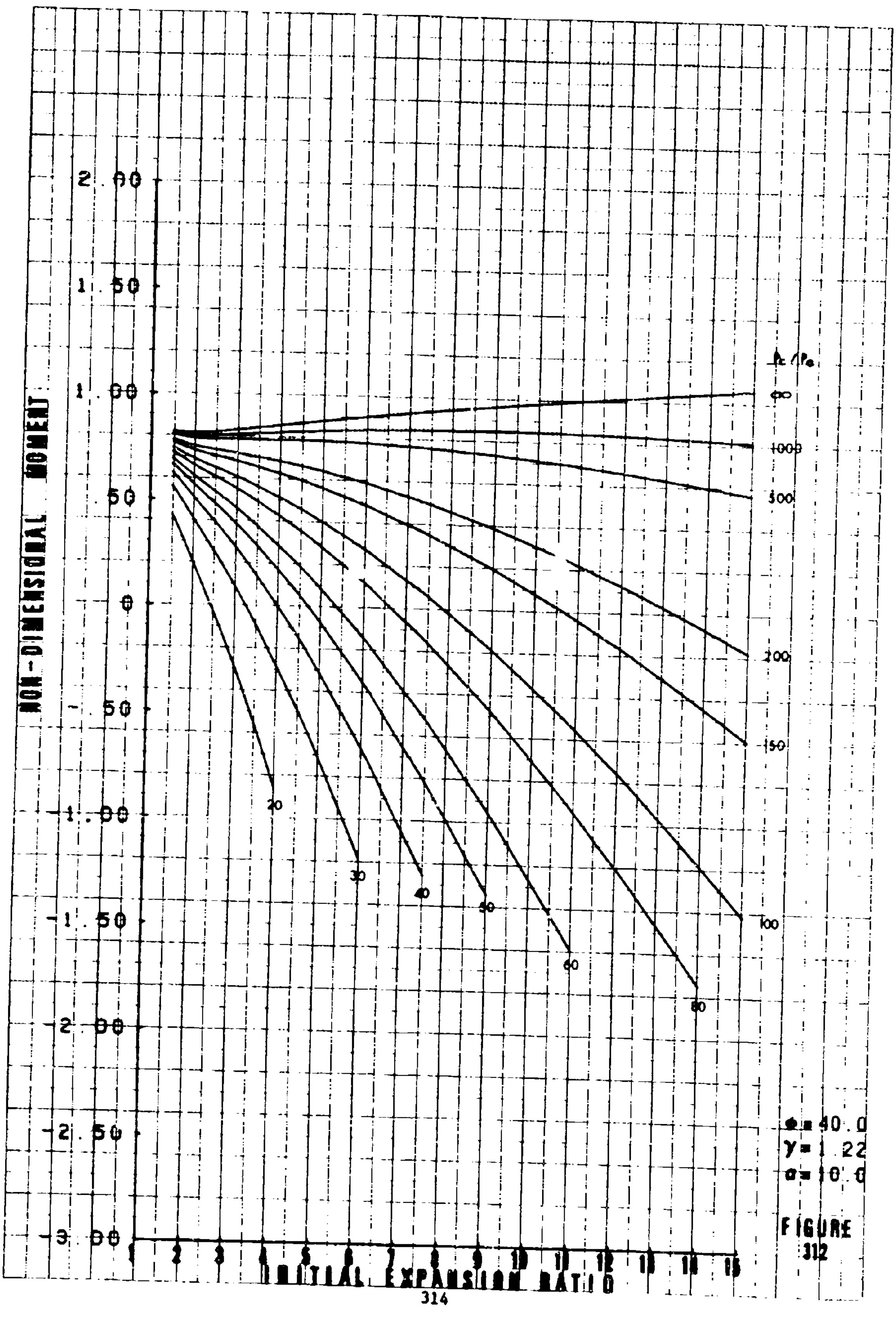

NON-DIMENSIONAL MOMENT
2.00
1.50
1.00
.50
0
-.50
-1.00
-1.50
-2.00
-2.50
-3.00
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
Pc/Pe
∞
1000
500
200
150
100
80
60
50
40
30
20
Φ= 40.0
γ= 1.22
α= 10.0

FIGURE 312

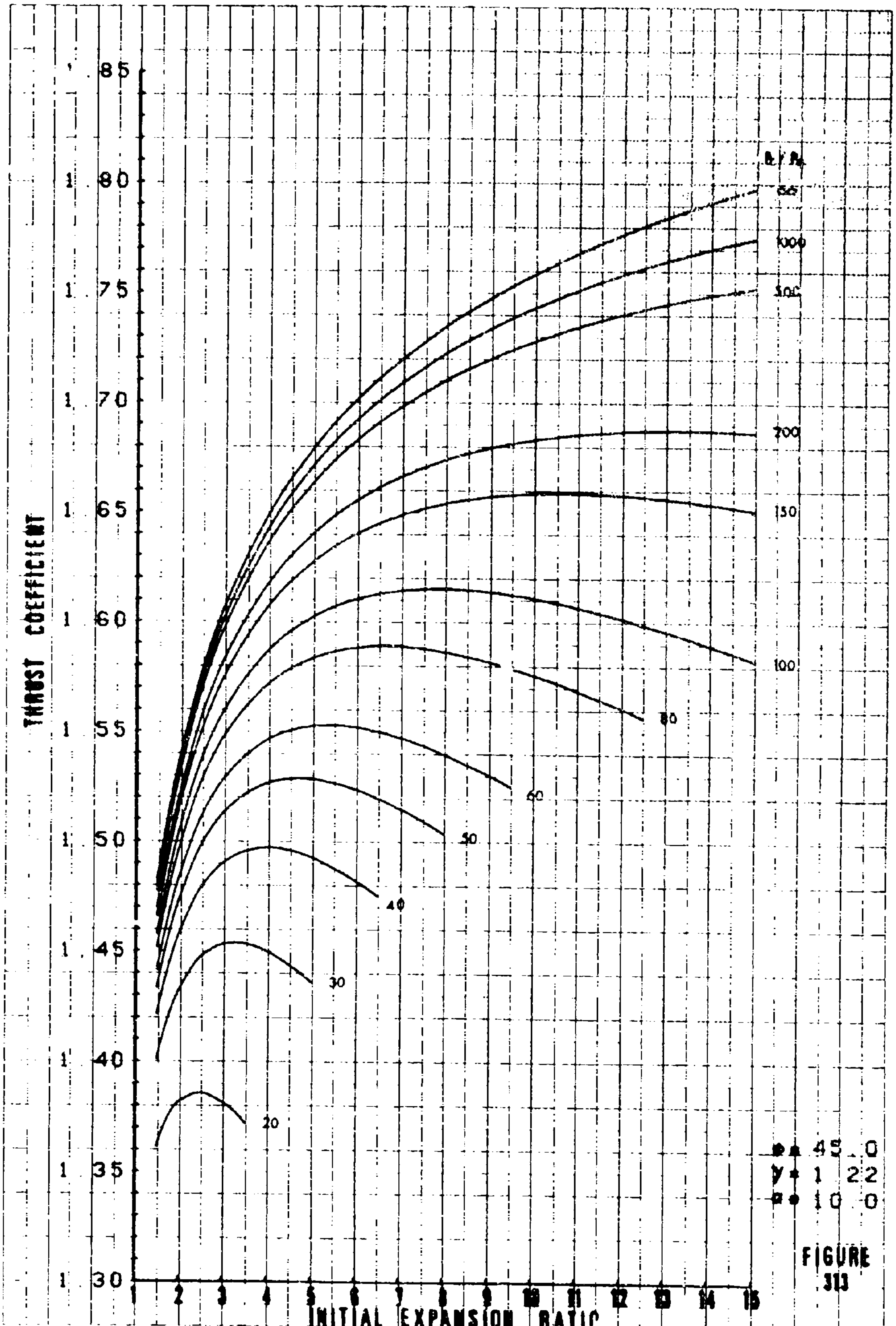
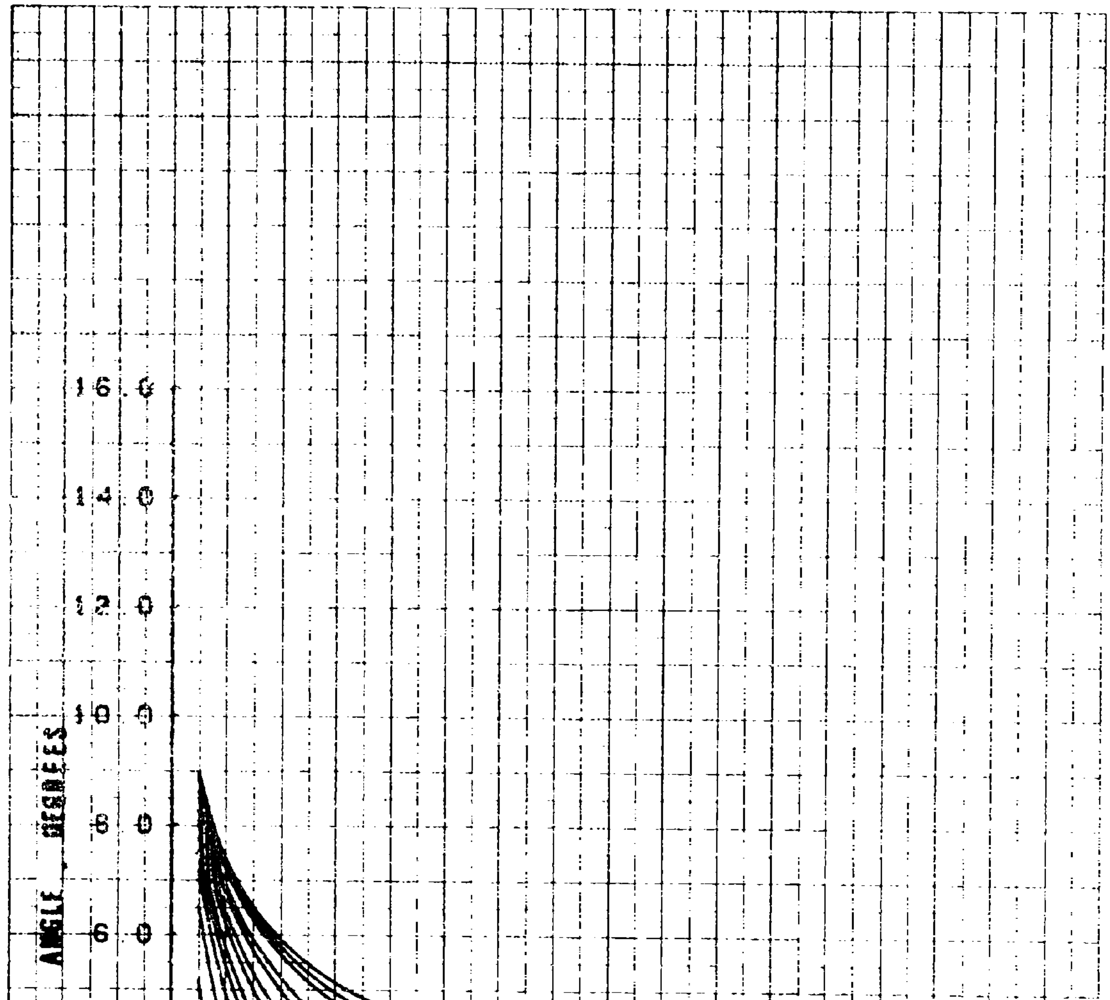

THRUST COEFFICIENT
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
INITIAL EXPANSION RATIO
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
1000
500
200
150
100
80
60
50
40
30
20
1.22
10.0

FIGURE 313


THRUST DEFLECTION ANGLE, DEGREES
INITIAL EXPANSION RATIO
P_c/P_a
∞
1000
500
200
150
100
80
60
50
40
30
20
Φ = 45.0
γ = 1.22
α = 18.0
FIGURE 314

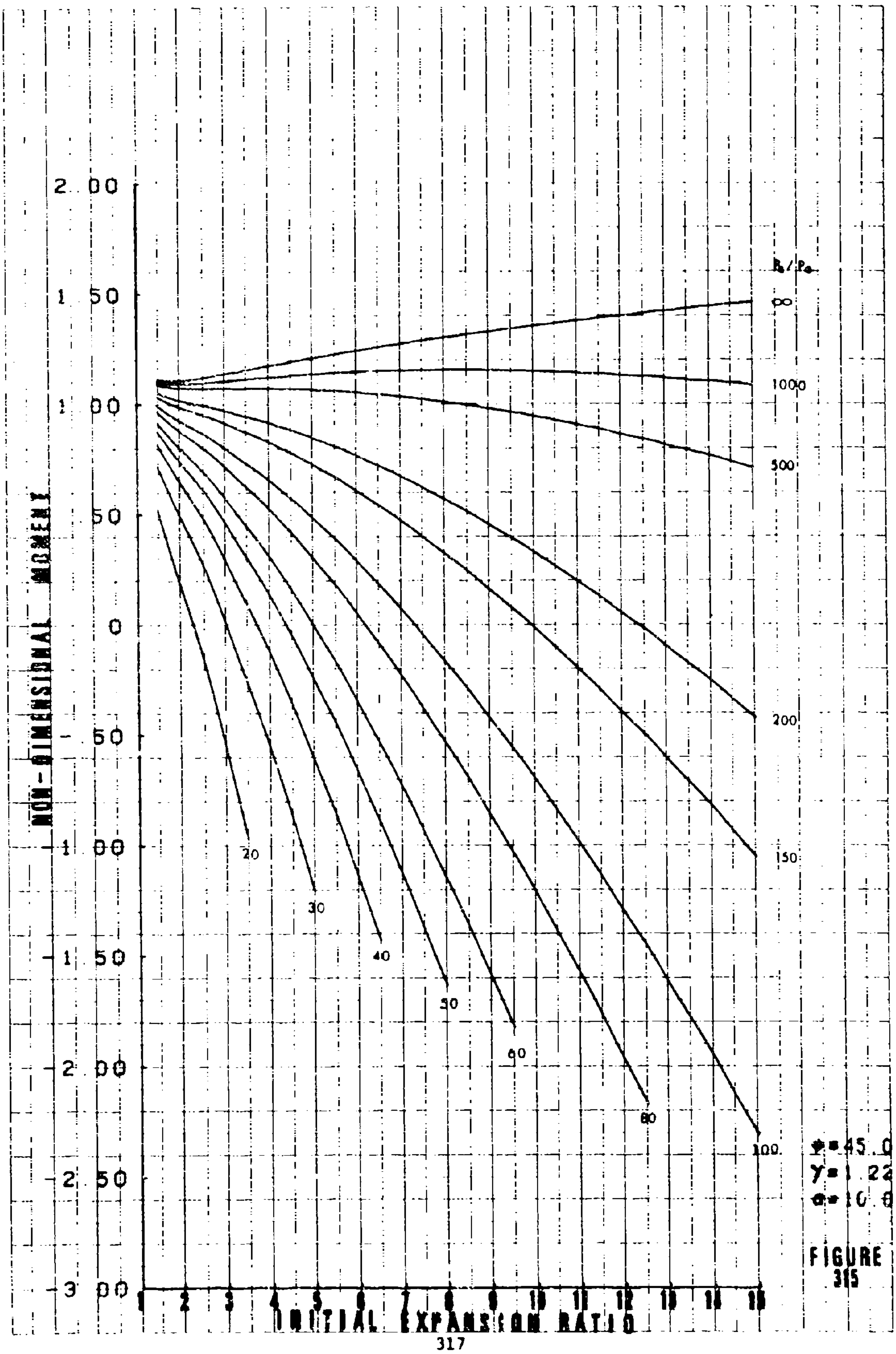
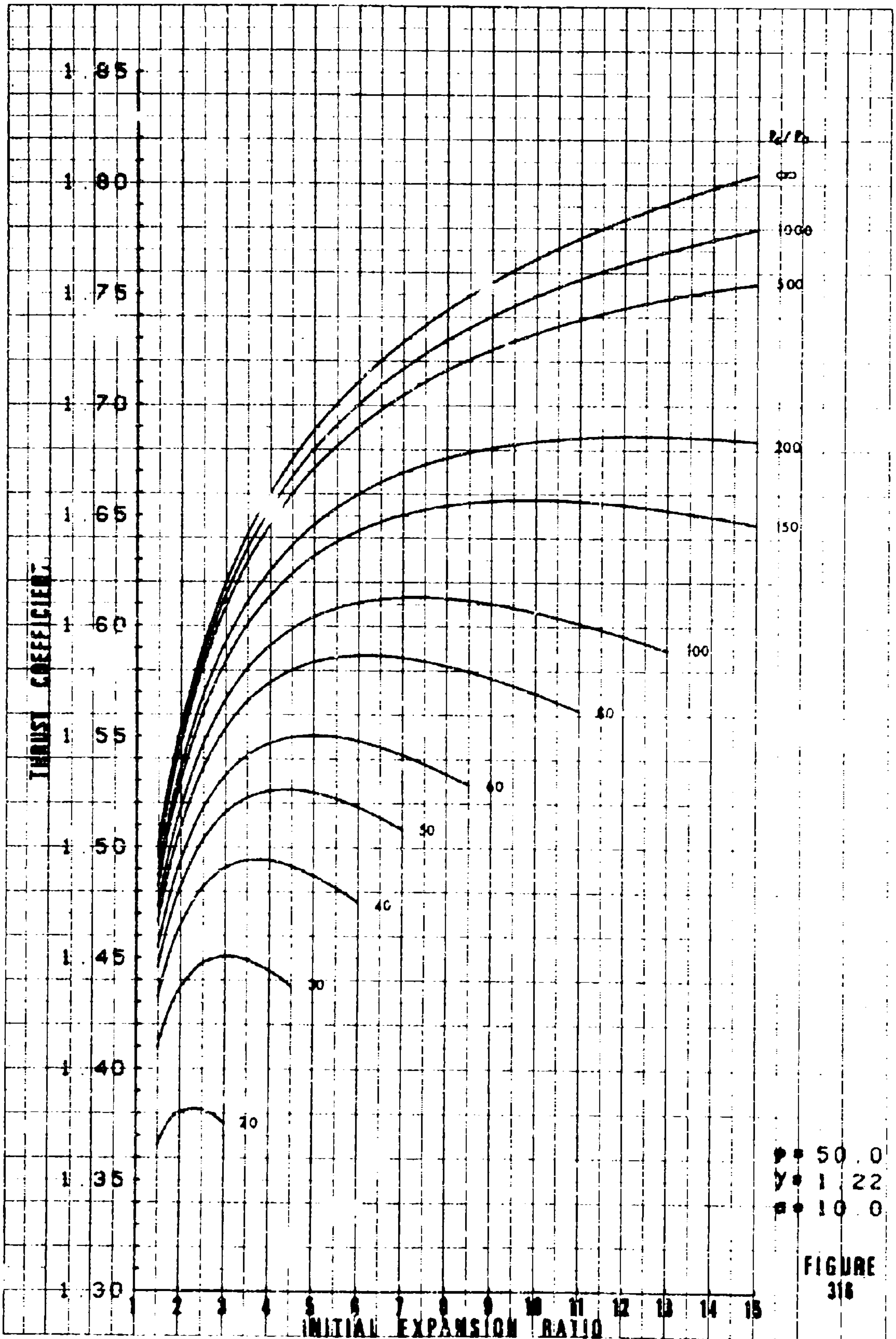

NON-DIMENSIONAL MOMENT
INITIAL EXPANSION RATIO
Pc/Pa
∞
1000
500
200
150
100
80
60
50
40
30
20
φ=45.0
γ=1.22
α=10.0

FIGURE 315



1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
THRUST COEFFICIENT
INITIAL EXPANSION RATIO
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
P_c/P_a
∞
1000
500
200
150
100
80
60
50
40
30
20
φ = 50.0
γ = 1.22
α = 10.0

FIGURE 318

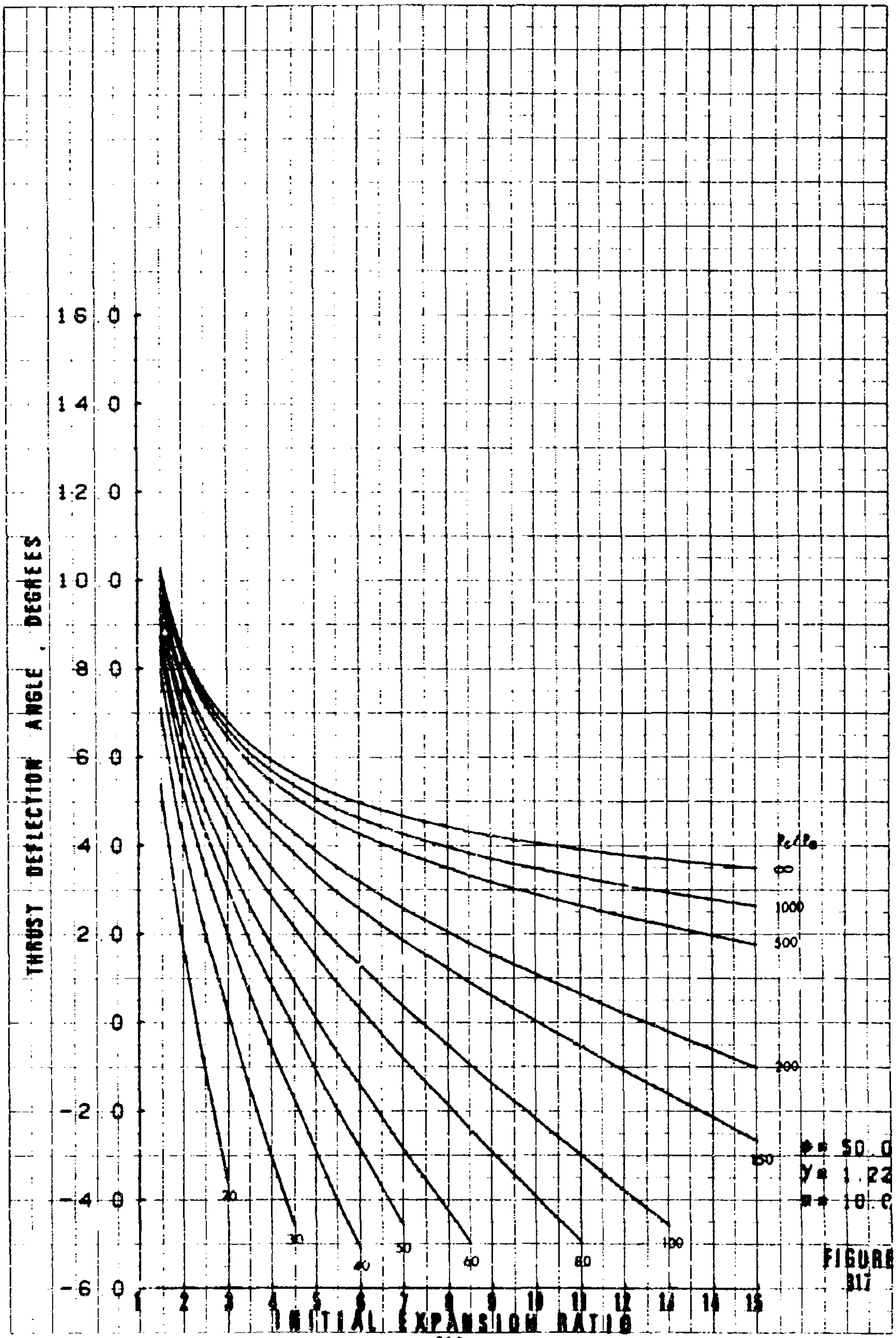
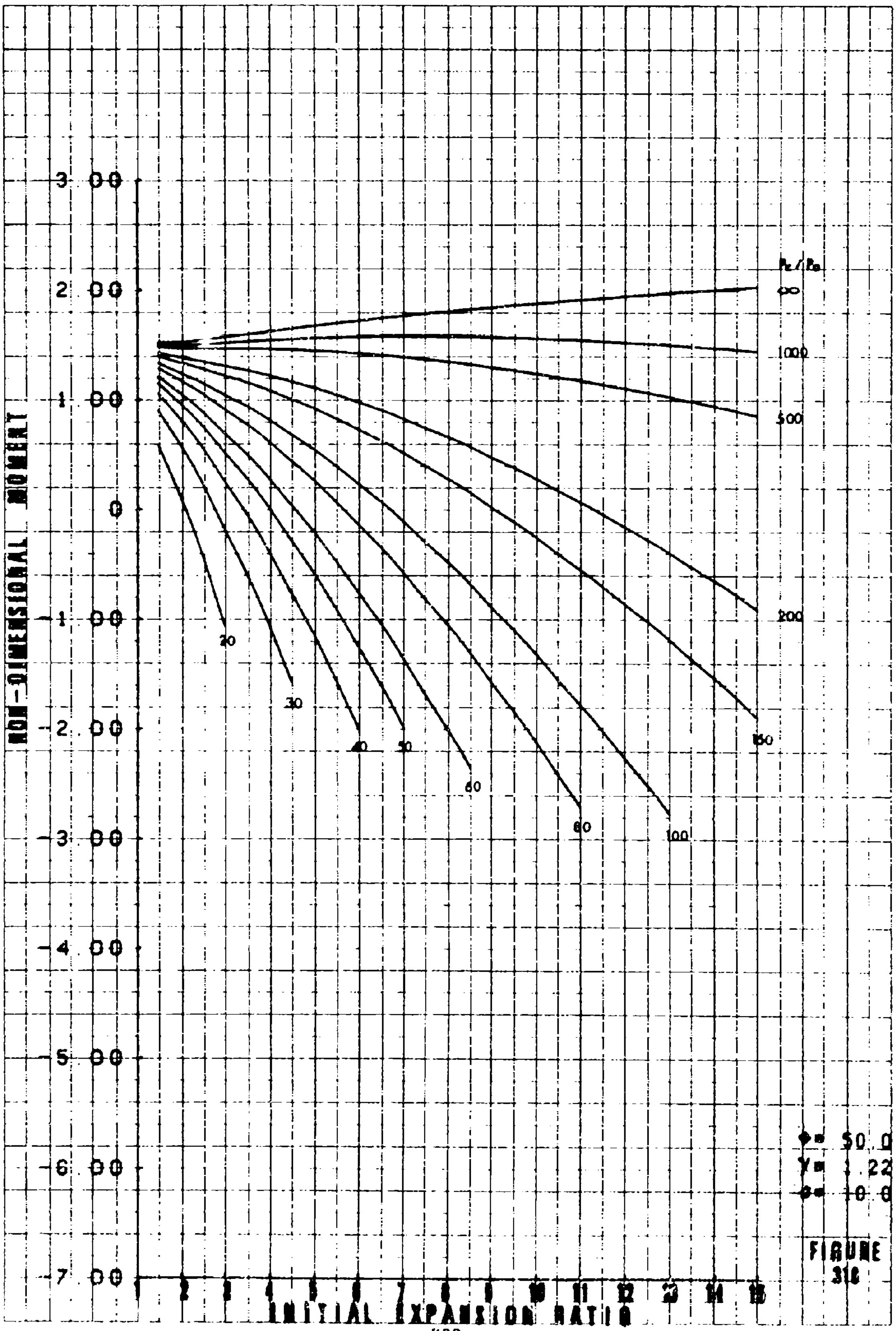
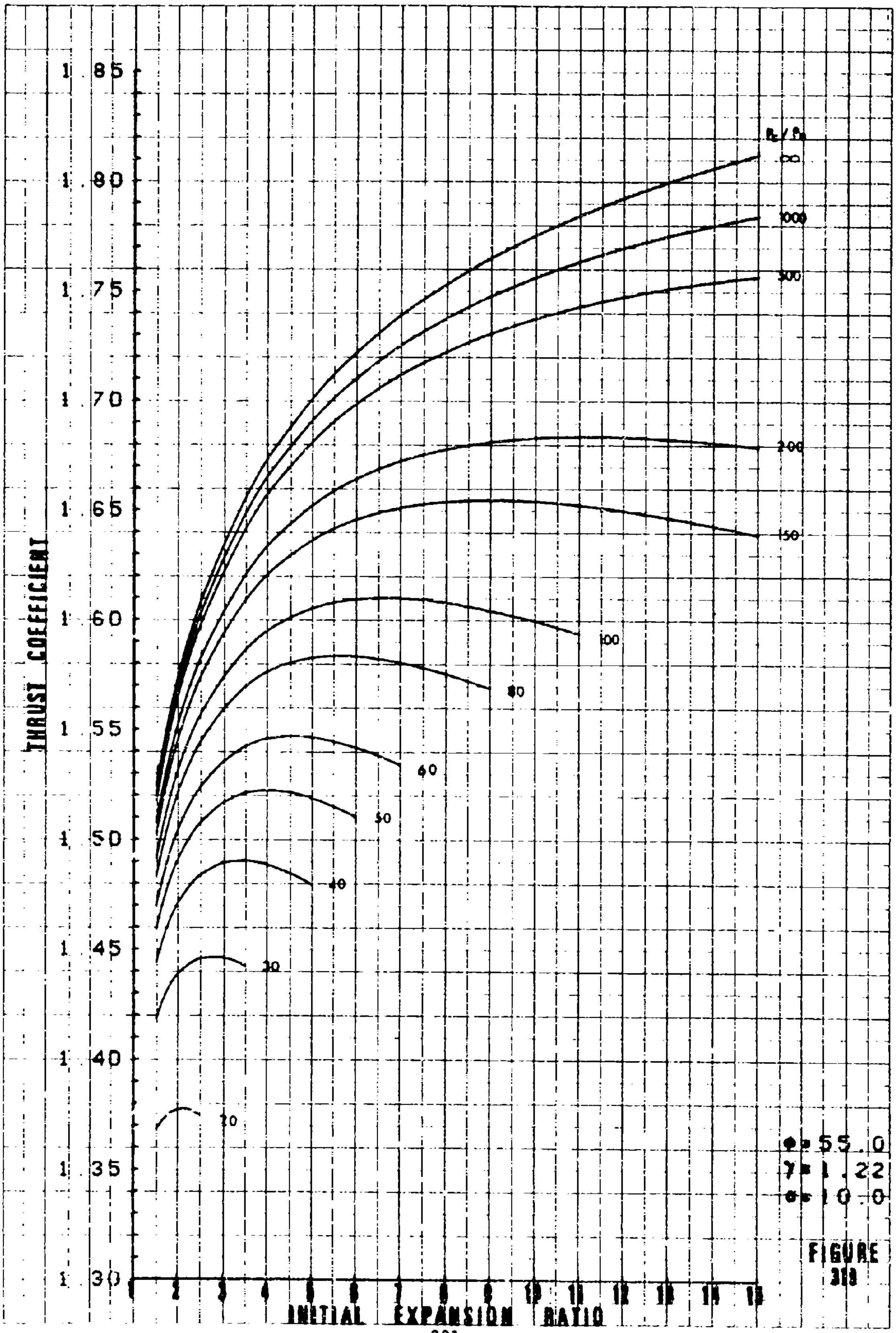

THRUST DEFLECTION ANGLE, DEGREES
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0
-2.0
-4.0
-6.0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
P_c/P_a
∞
1000
500
200
150
100
80
60
50
40
30
20
= 50.0
γ = 1.22
= 10.0

FIGURE 317



NON-DIMENSIONAL MOMENT
3.00
2.00
1.00
0
-1.00
-2.00
-3.00
-4.00
-5.00
-6.00
-7.00
Pc/Pa
∞
1000
500
200
150
100
80
60
50
40
30
20
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
INITIAL EXPANSION RATIO
φ= 50.0
γ= 1.22
θ= 10.0
FIGURE 318


THRUST COEFFICIENT
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
INITIAL EXPANSION RATIO
∞
1000
500
200
150
100
80
60
50
40
30
20
Φ=55.0
γ=1.22
ε=10.0
FIGURE
318

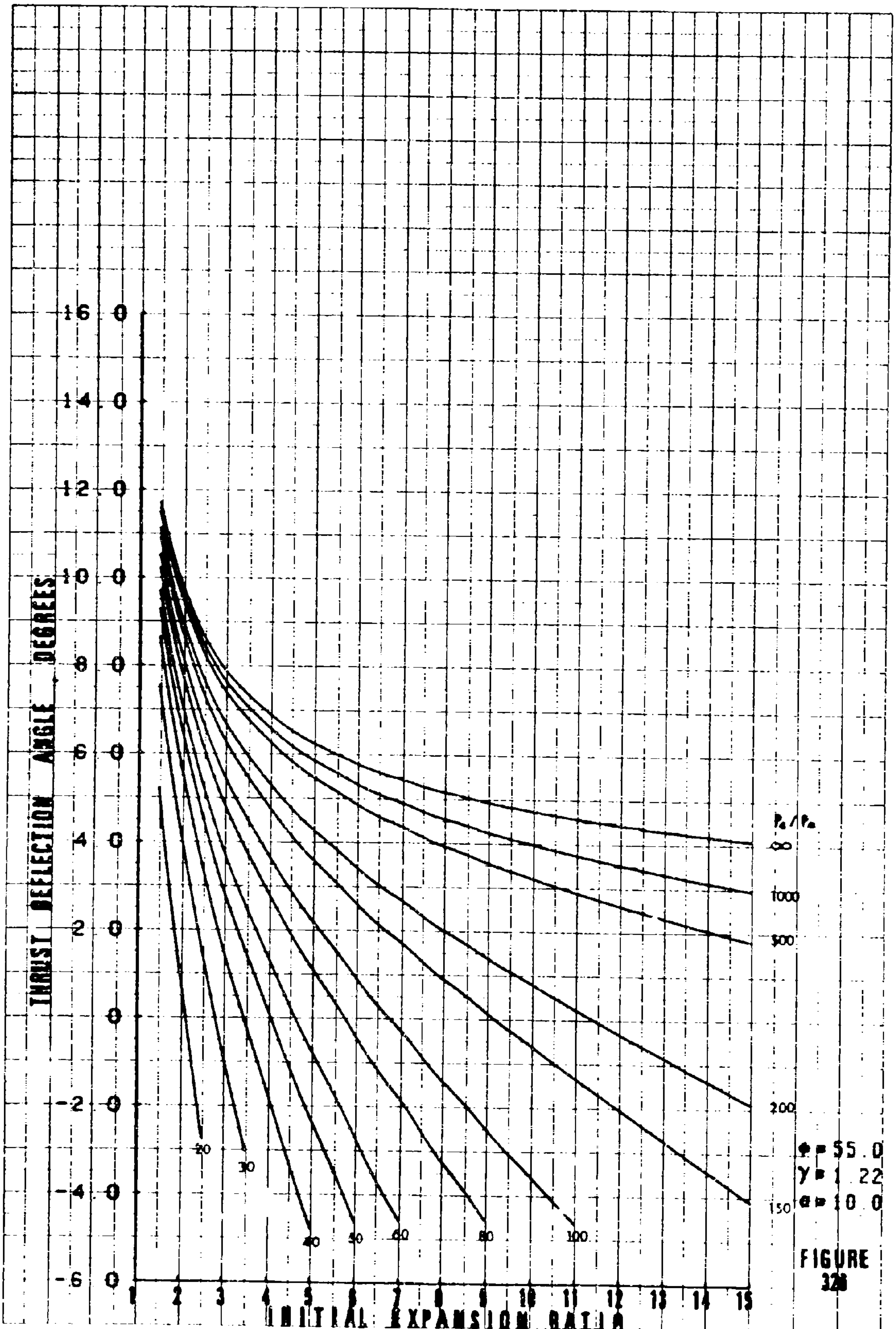
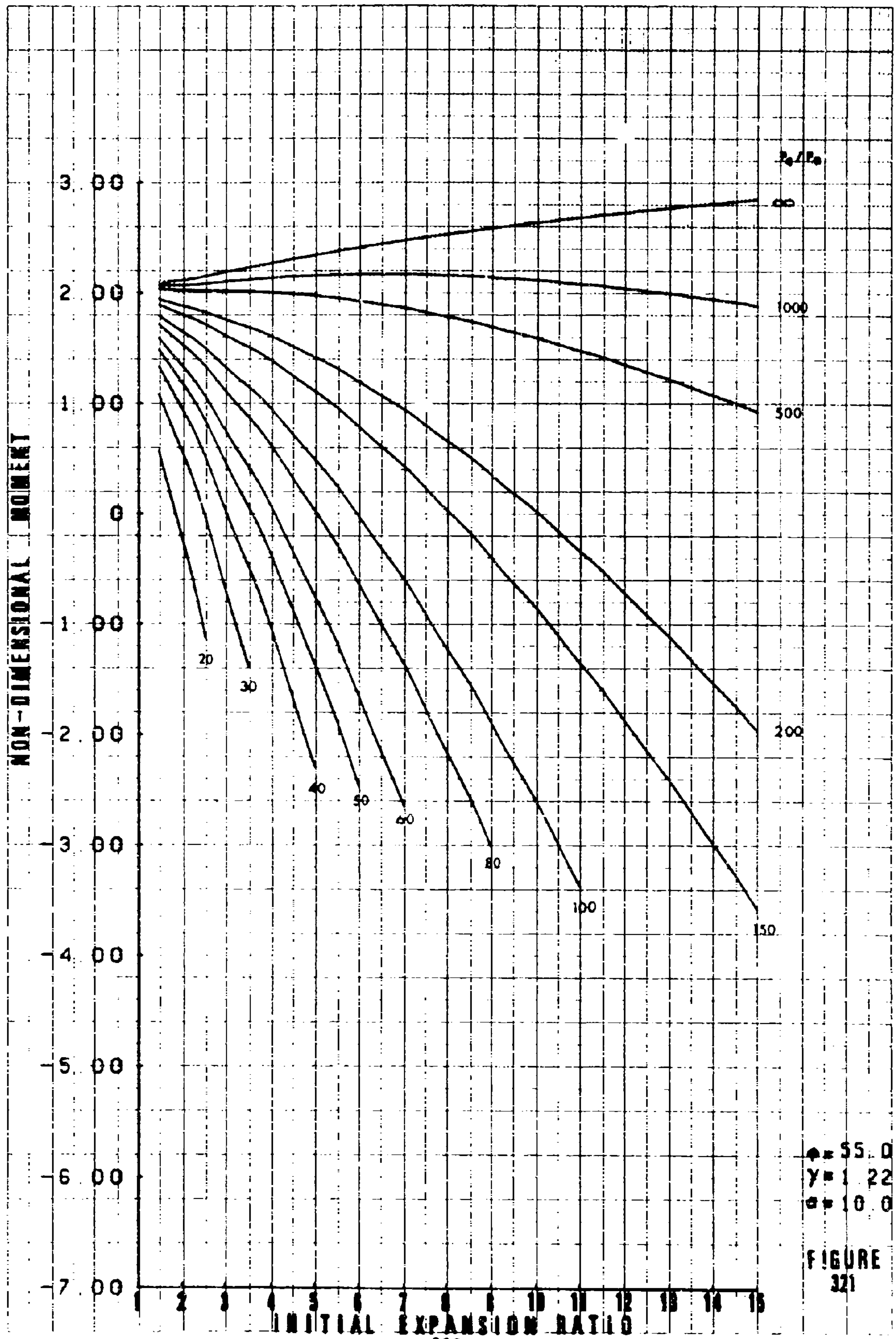

THRUST DEFLECTION ANGLE DEGREES
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0
-2.0
-4.0
-6.0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
INITIAL EXPANSION RATIO
∞
1000
500
200
150
20
30
40
50
60
80
100
Φ = 55.0
γ = 1.22
ε = 10.0

FIGURE 32



P_c/P_a
∞
1000
500
200
150
100
80
60
50
40
30
20
3.00
2.00
1.00
0
-1.00
-2.00
-3.00
-4.00
-5.00
-6.00
-7.00
NON-DIMENSIONAL MOMENT
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
φ = 55.0
γ = 1.22
α = 10.0

FIGURE 321

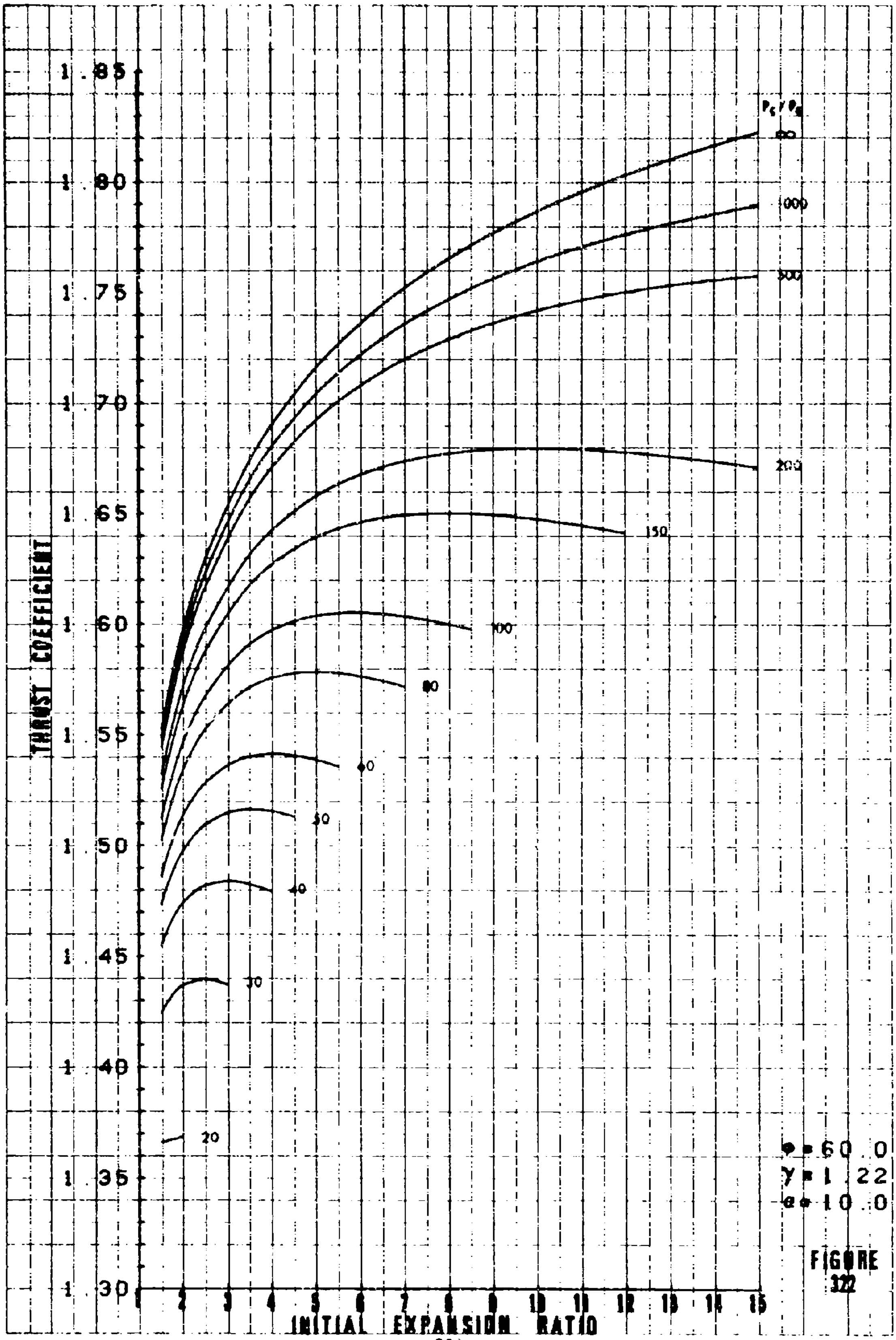

THRUST COEFFICIENT
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
P_c/P_e
∞
1000
500
200
150
100
80
60
50
40
30
20
ϕ = 60.0
γ = 1.22
ϵ = 10.0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO

FIGURE 322

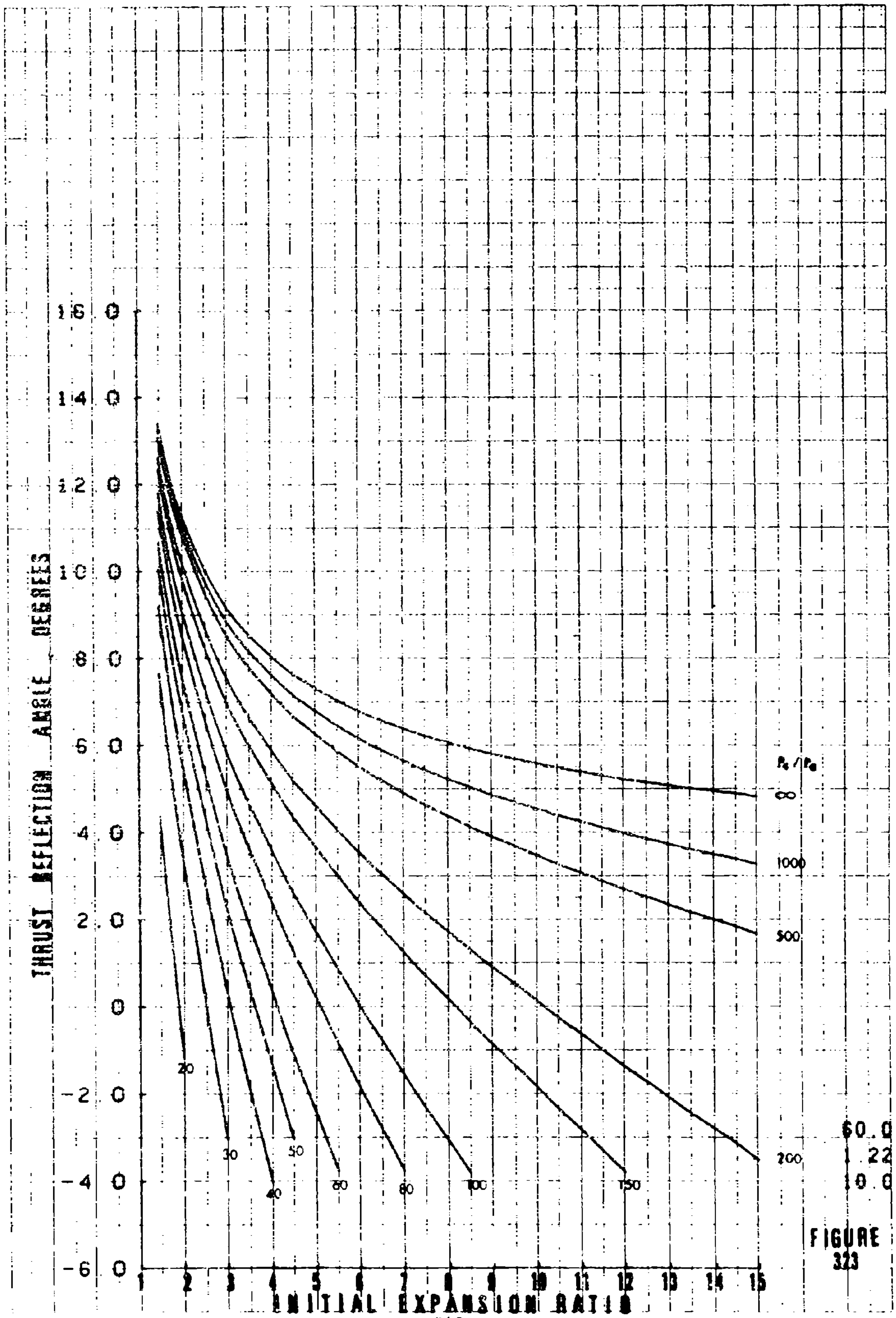
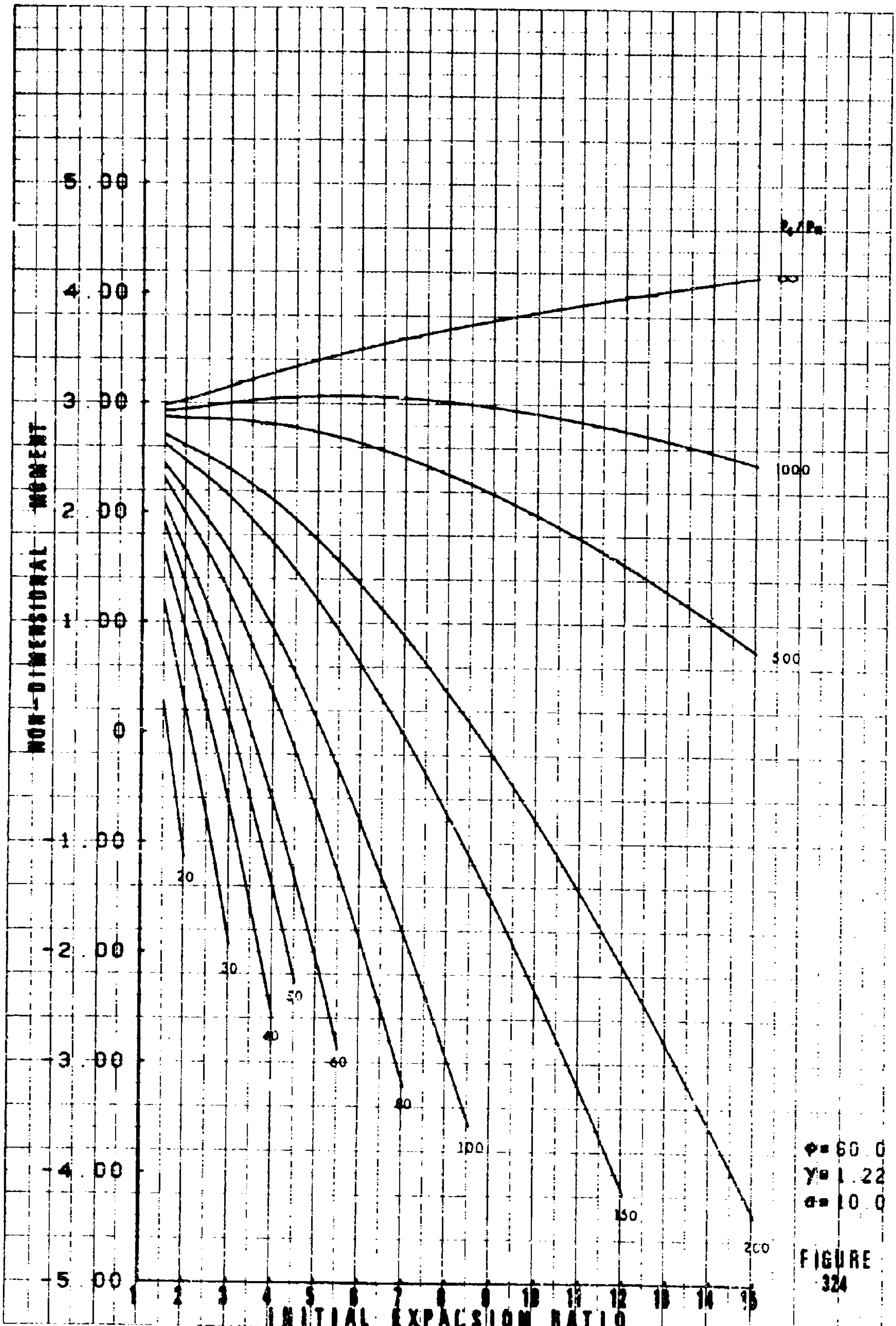

THRUST REFLECTION ANGLE DEGREES
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0
-2.0
-4.0
-6.0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
INITIAL EXPANSION RATIO
P_c/P_a
∞
1000
500
200
20
30
40
50
60
80
100
150
60.0
1.22
10.0

FIGURE 323



NON-DIMENSIONAL MOMENT
5.00
4.00
3.00
2.00
1.00
0
-1.00
-2.00
-3.00
-4.00
-5.00
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
P_c/P_a
∞
1000
500
200
150
100
80
60
50
40
30
20
Φ= 60.0
γ= 1.22
α= 10.0

FIGURE 324

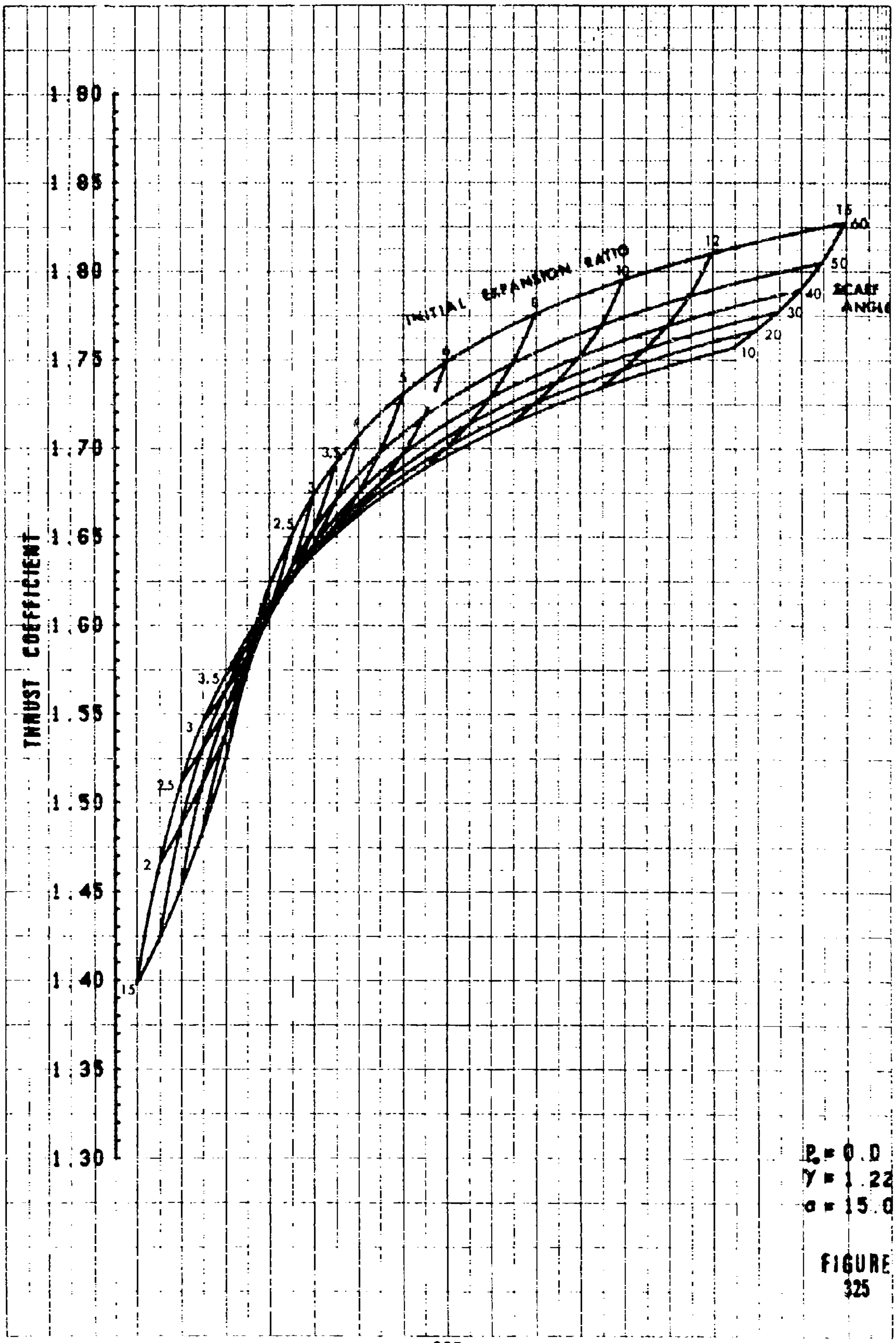

THRUST COEFFICIENT
1.90
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
INITIAL EXPANSION RATIO
SCARF ANGLE
$P_o = 0.0$
$\gamma = 1.22$
$\alpha = 15.0$

FIGURE 325

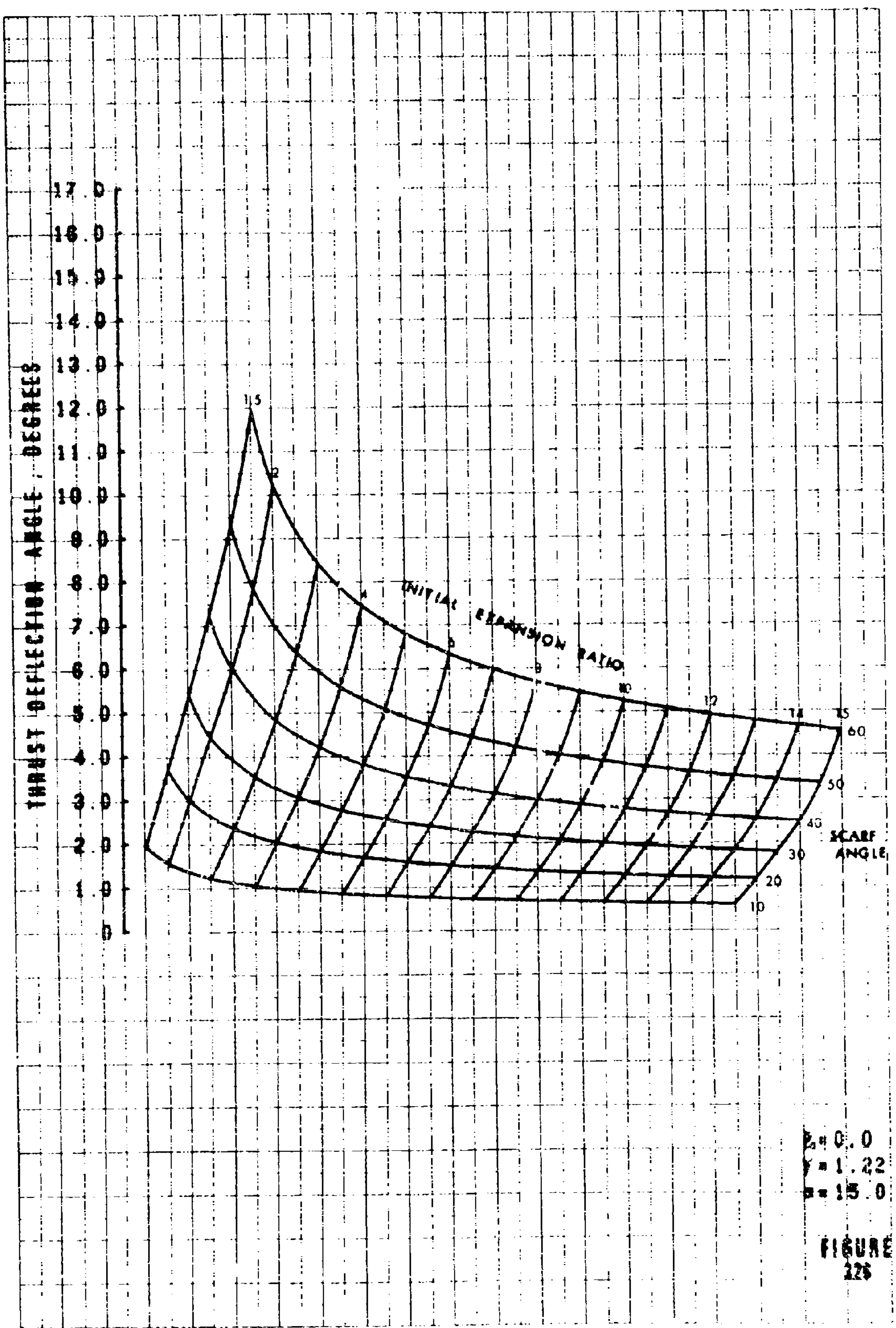

THRUST DEFLECTION ANGLE, DEGREES
17.0
16.0
15.0
14.0
13.0
12.0
11.0
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
INITIAL EXPANSION RATIO
1.5
2
4
6
8
10
12
14
15
60
50
40
30
20
10
SCARF ANGLE
P_a = 0.0
γ = 1.22
= 15.0

FIGURE 226

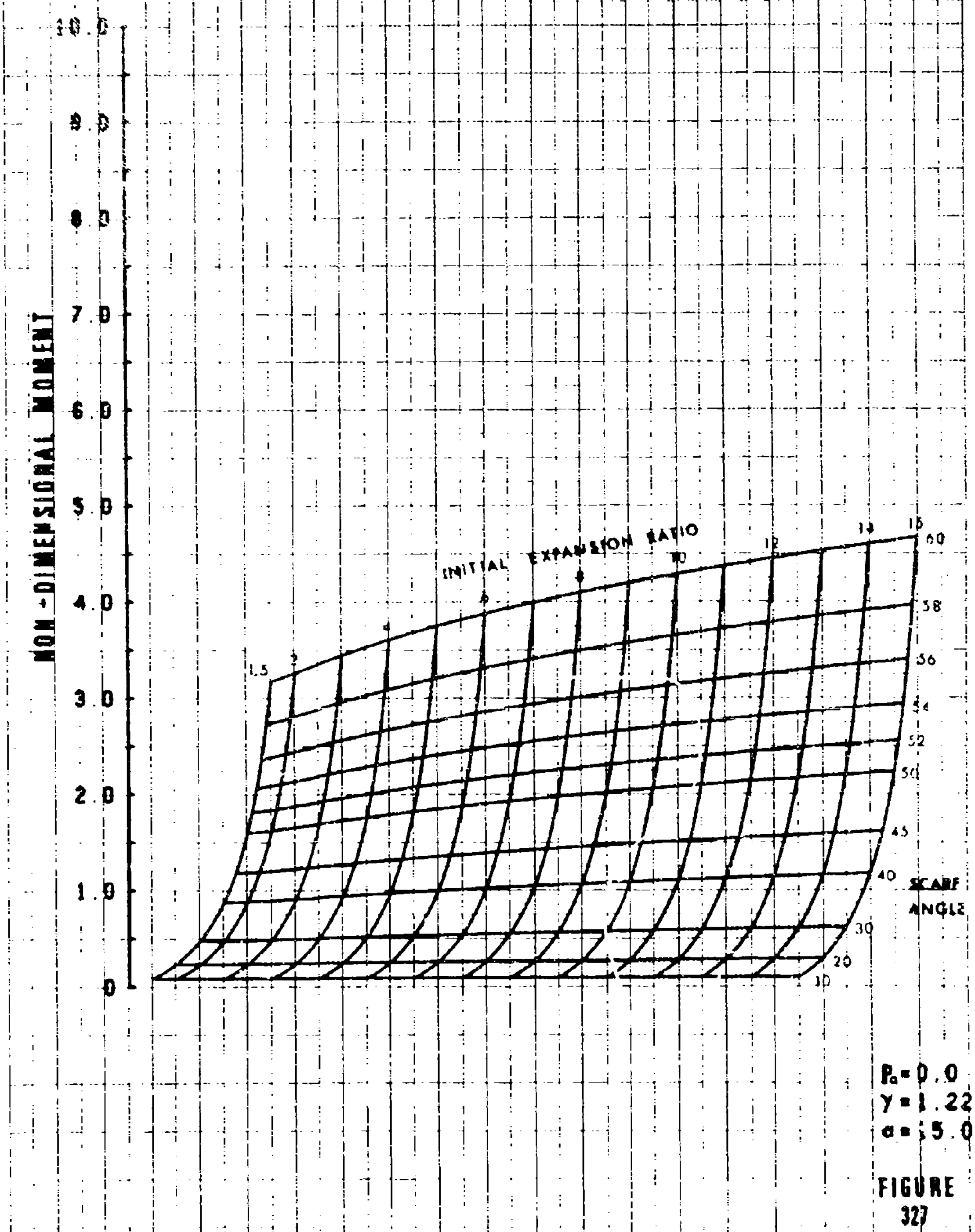

NON-DIMENSIONAL MOMENT
INITIAL EXPANSION RATIO
SCARF ANGLE
$P_a = 0.0$
$\gamma = 1.22$
$\alpha = 15.0$

FIGURE 327

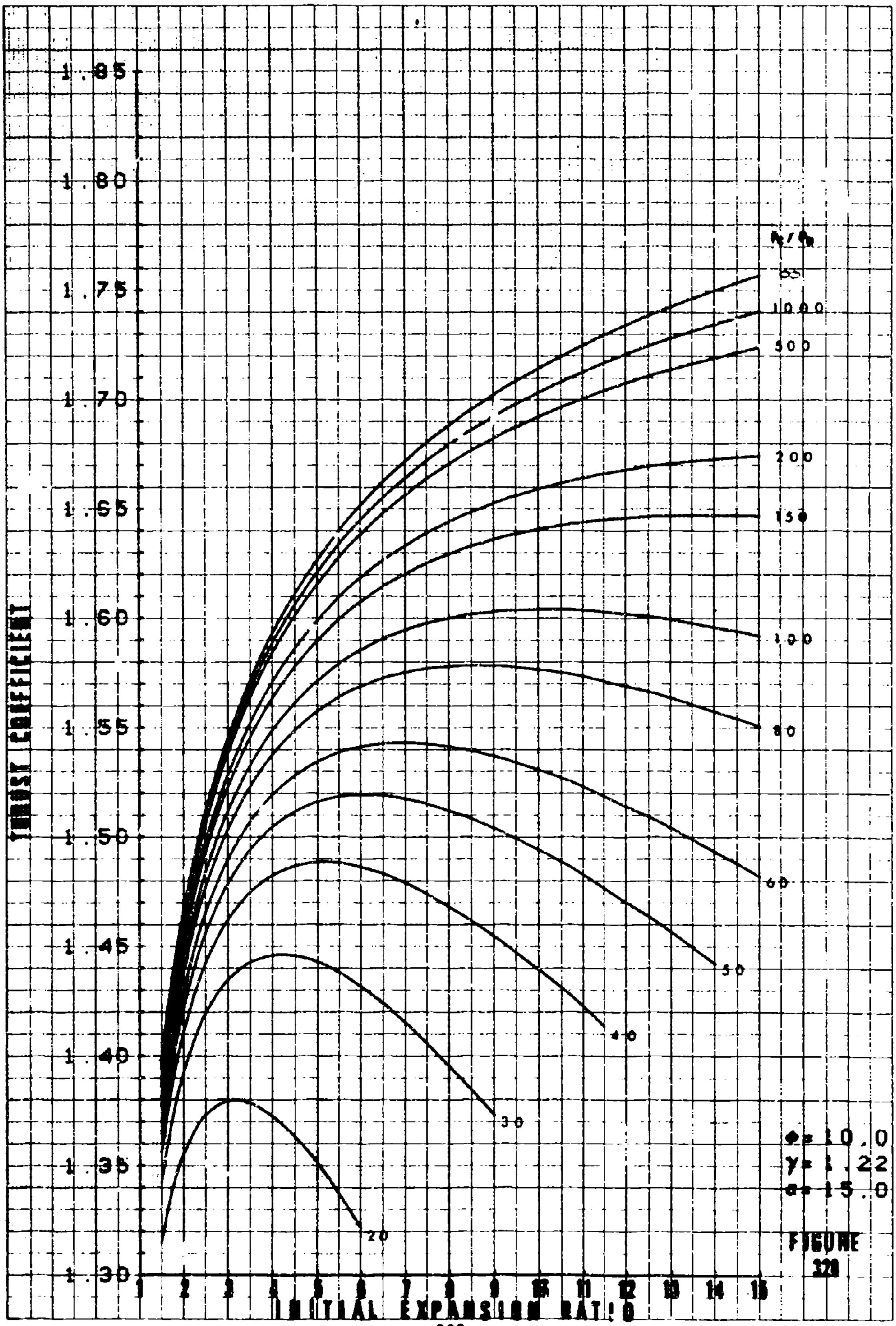

THRUST COEFFICIENT
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
1000
500
200
150
100
80
60
50
40
30
20
Φ= 10.0
γ= 1.22
α= 15.0

FIGURE 328

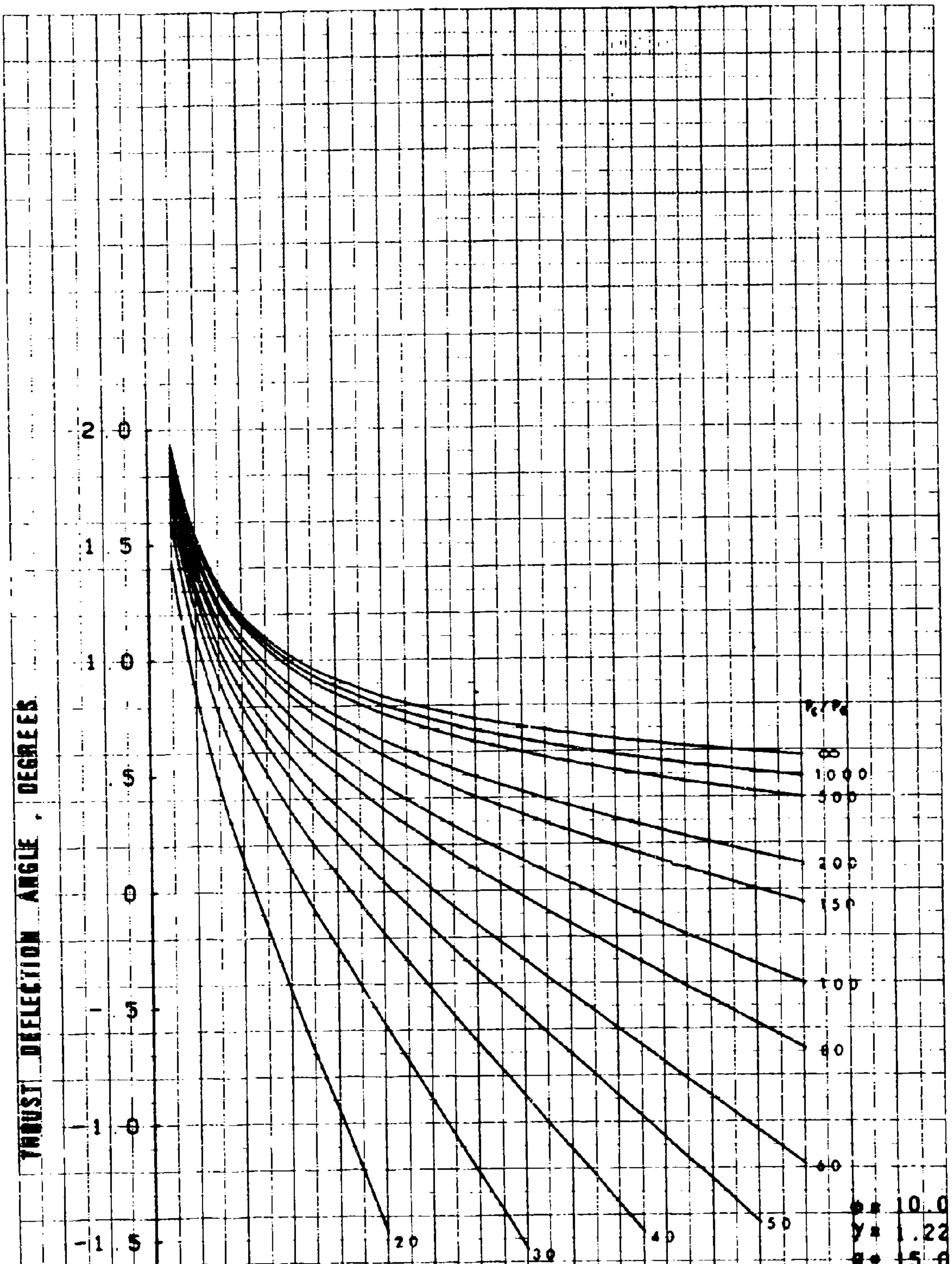

THRUST DEFLECTION ANGLE , DEGREES
INITIAL EXPANSION RATIO
2.0
1.5
1.0
.5
0
-.5
-1.0
-1.5
-2.0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
P_c/P_e
∞
1000
500
200
150
100
80
60
50
40
30
20
θ= 10.0
γ= 1.22
α= 15.0

FIGURE 320

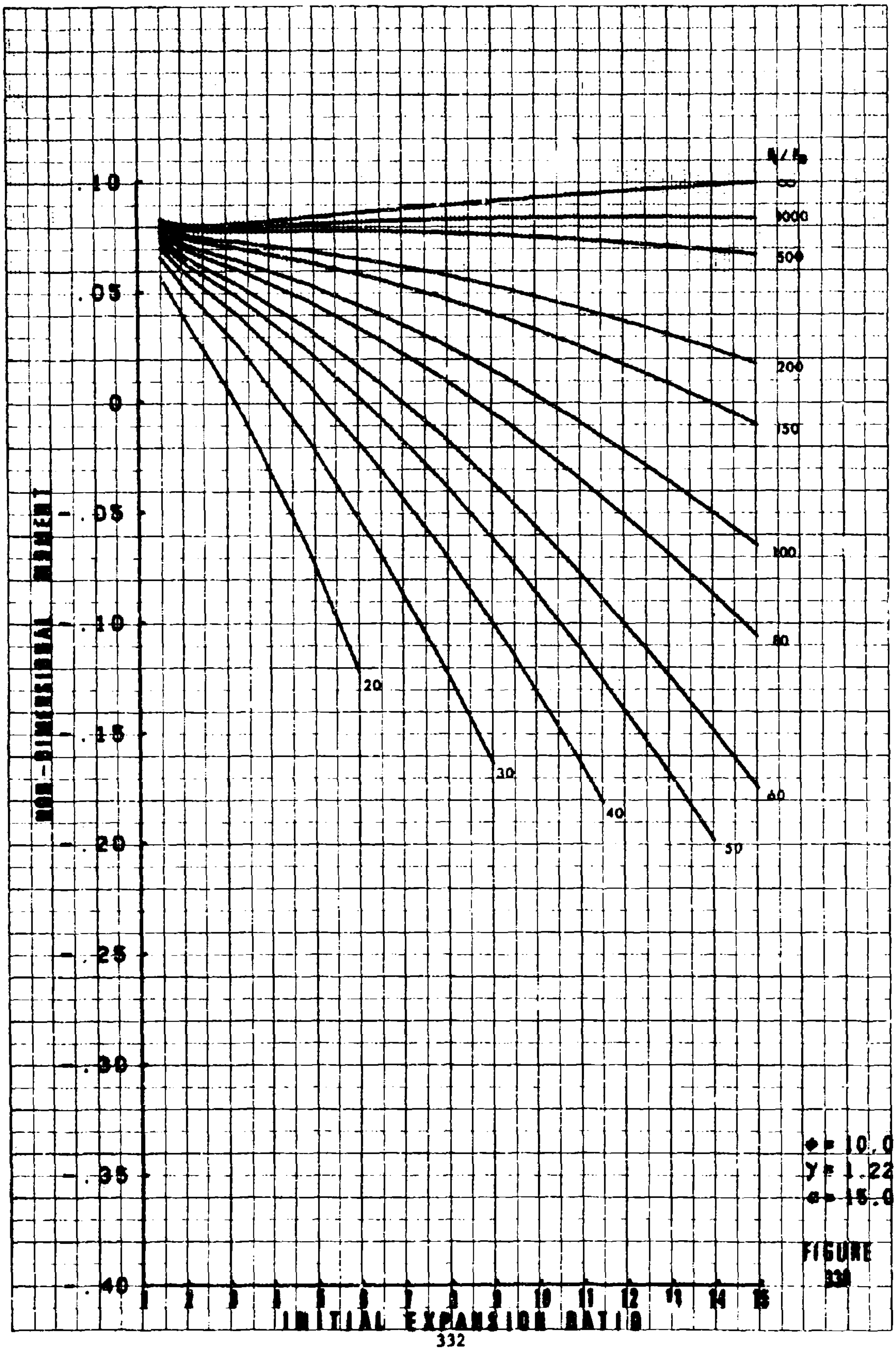
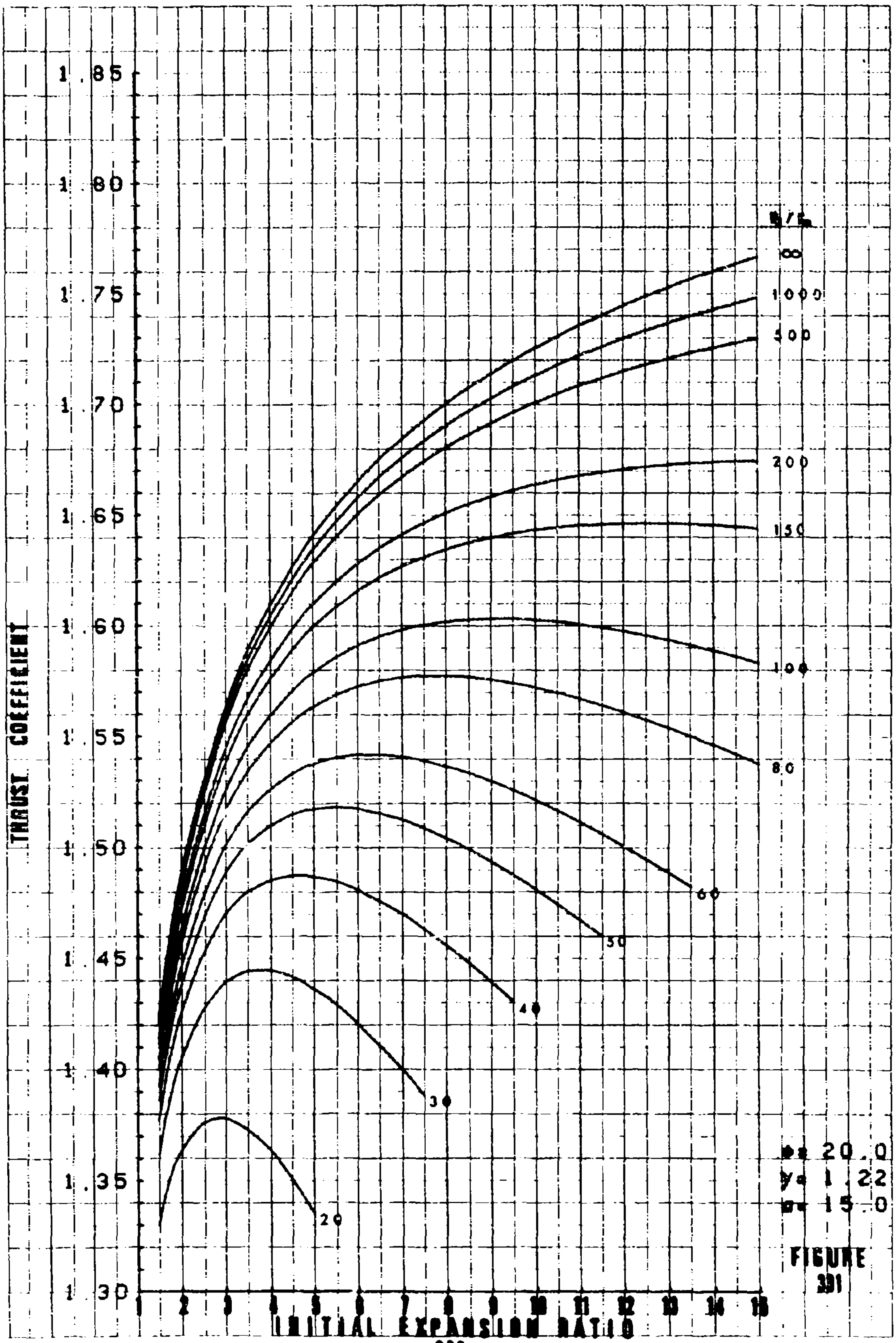

N/F
∞
1000
500
200
150
100
80
60
50
40
30
20
.10
.05
0
-.05
-.10
-.15
-.20
-.25
-.30
-.35
-.40
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
NON-DIMENSIONAL MOMENT
INITIAL EXPANSION RATIO
φ = 10.0
γ = 1.22
α = 15.0

FIGURE 33


THRUST COEFFICIENT
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
INITIAL EXPANSION RATIO
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
∞
1000
500
200
150
100
80
60
50
40
30
20
20.0
1.22
15.0
FIGURE
331

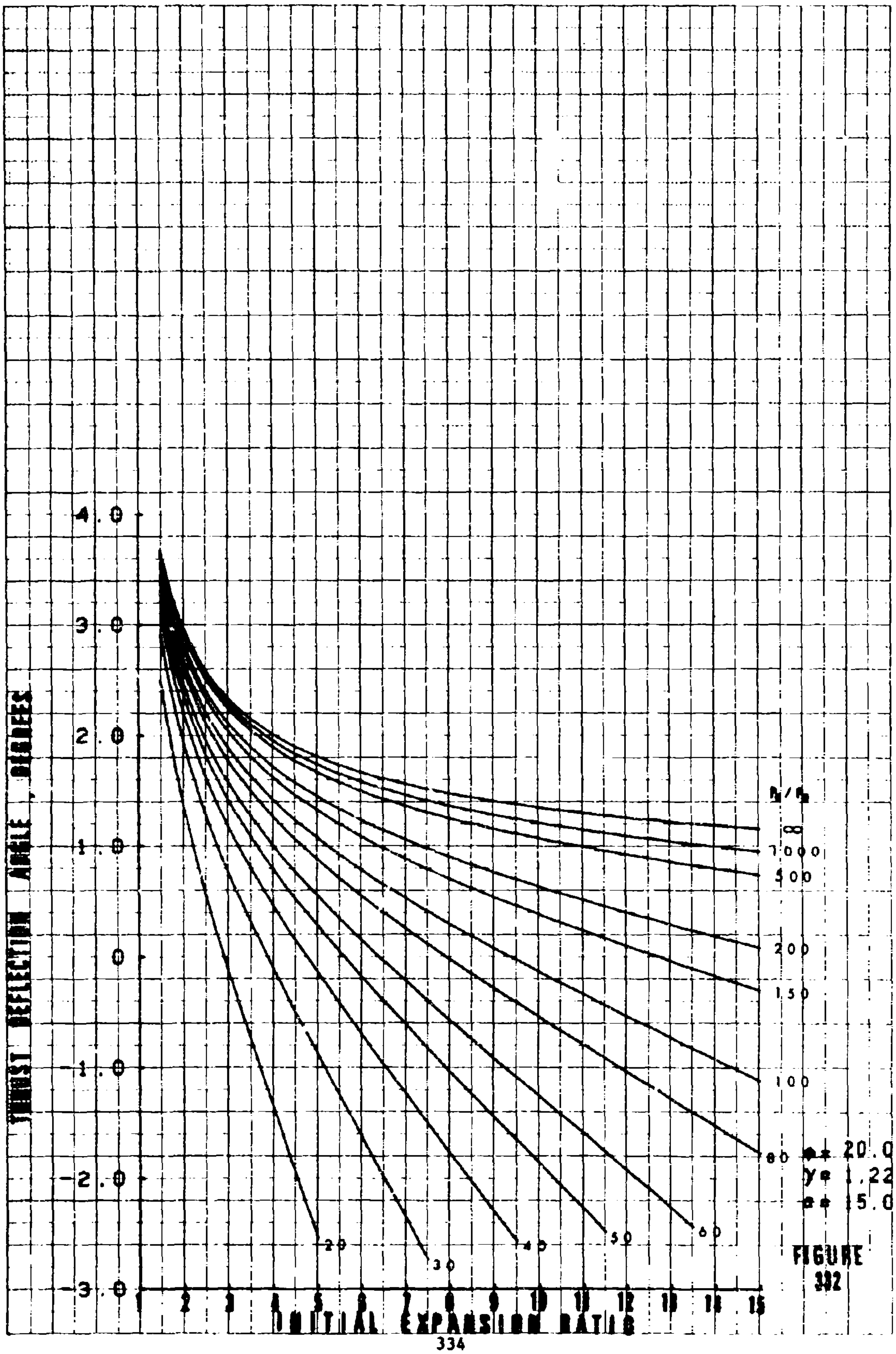
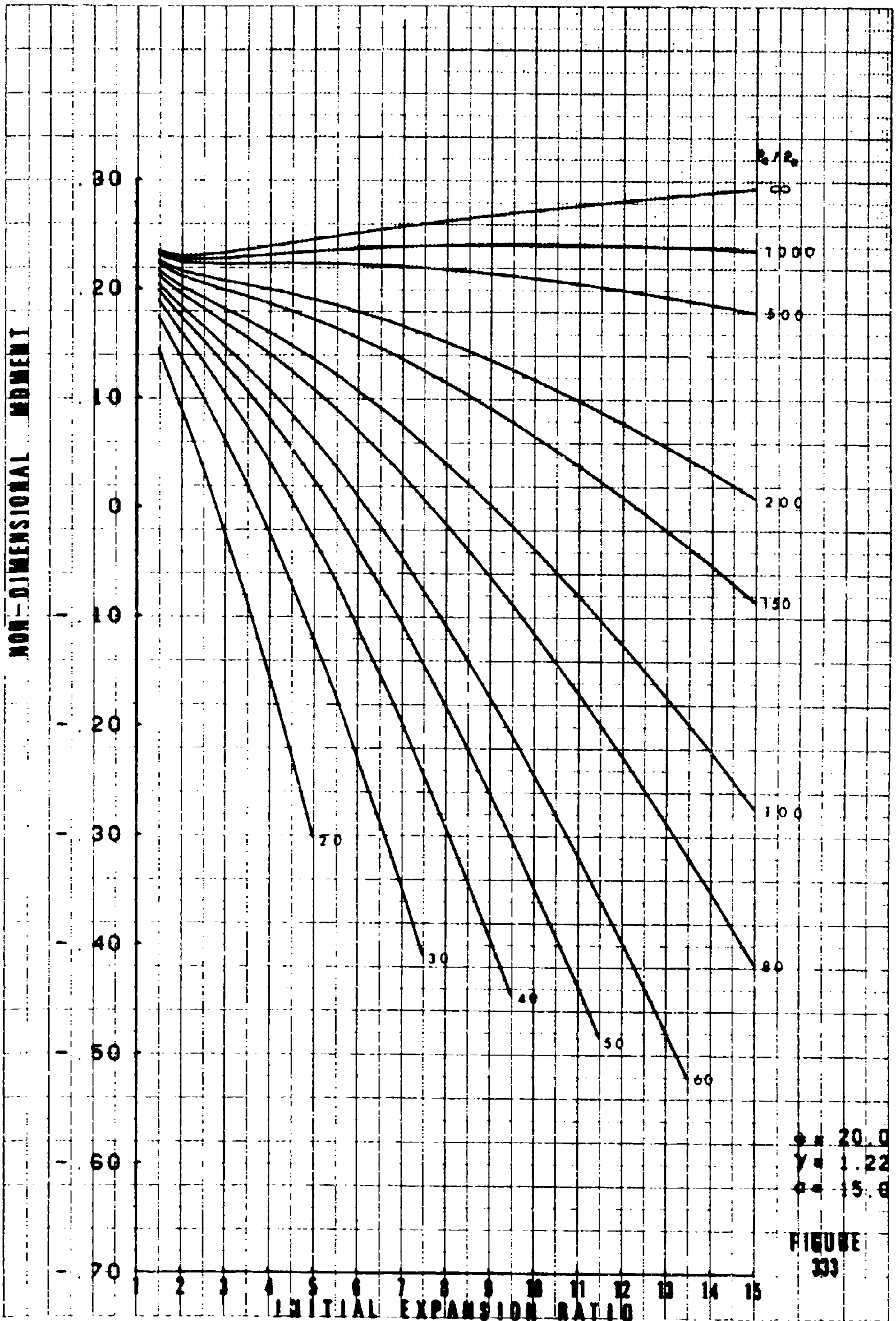

THRUST DEFLECTION ANGLE, DEGREES
INITIAL EXPANSION RATIO
4.0
3.0
2.0
1.0
0
-1.0
-2.0
-3.0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
∞
1000
500
200
150
100
80
60
50
40
30
20
20.0
γ= 1.22
15.0

FIGURE
332



NON-DIMENSIONAL MOMENT
INITIAL EXPANSION RATIO
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
P_c/P_a
∞
1000
500
200
150
100
80
60
50
40
30
20

FIGURE 333

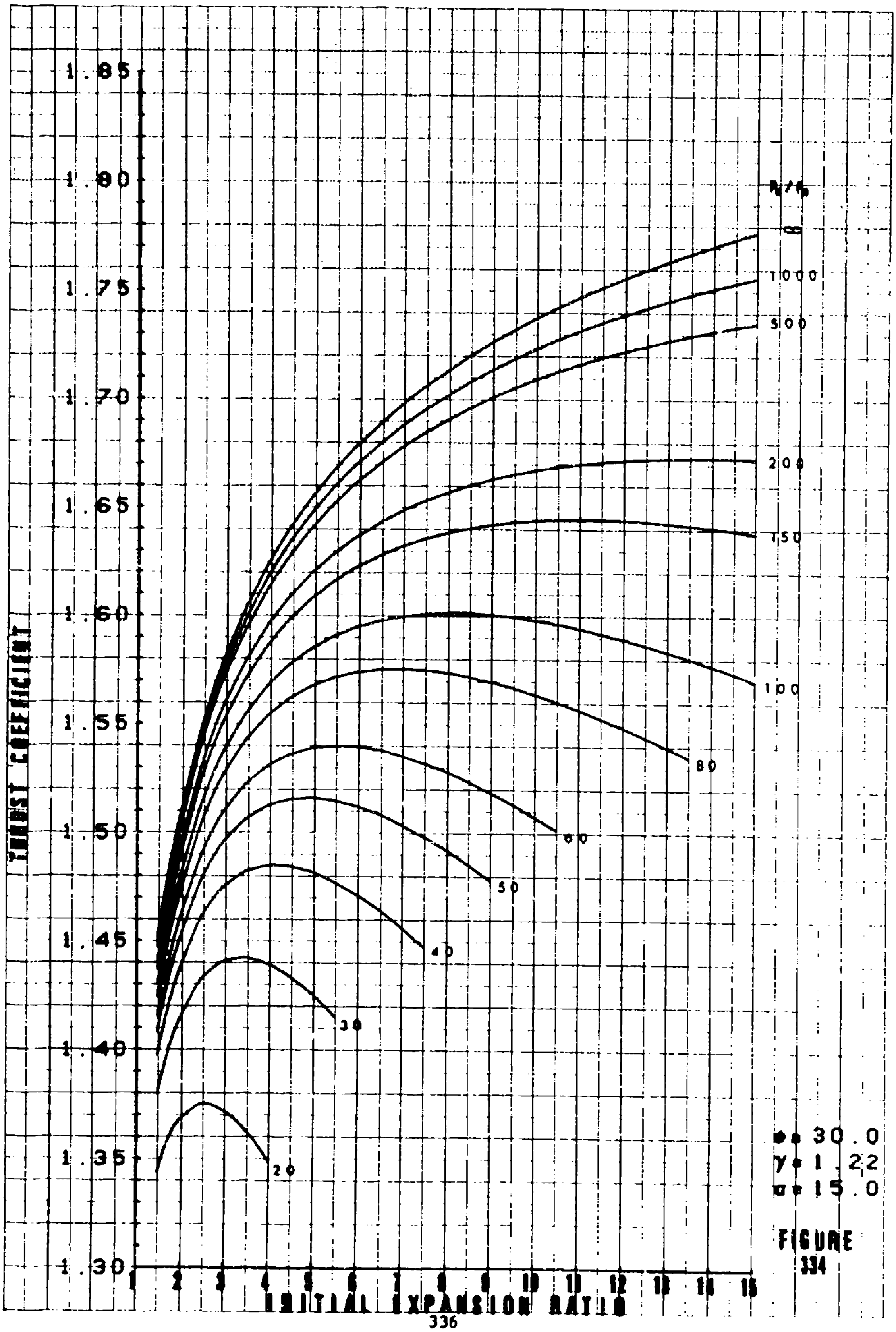

THRUST COEFFICIENT
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
INITIAL EXPANSION RATIO
∞
1000
500
200
150
100
80
60
50
40
30
20
θ = 30.0
γ = 1.22
α = 15.0

FIGURE 334

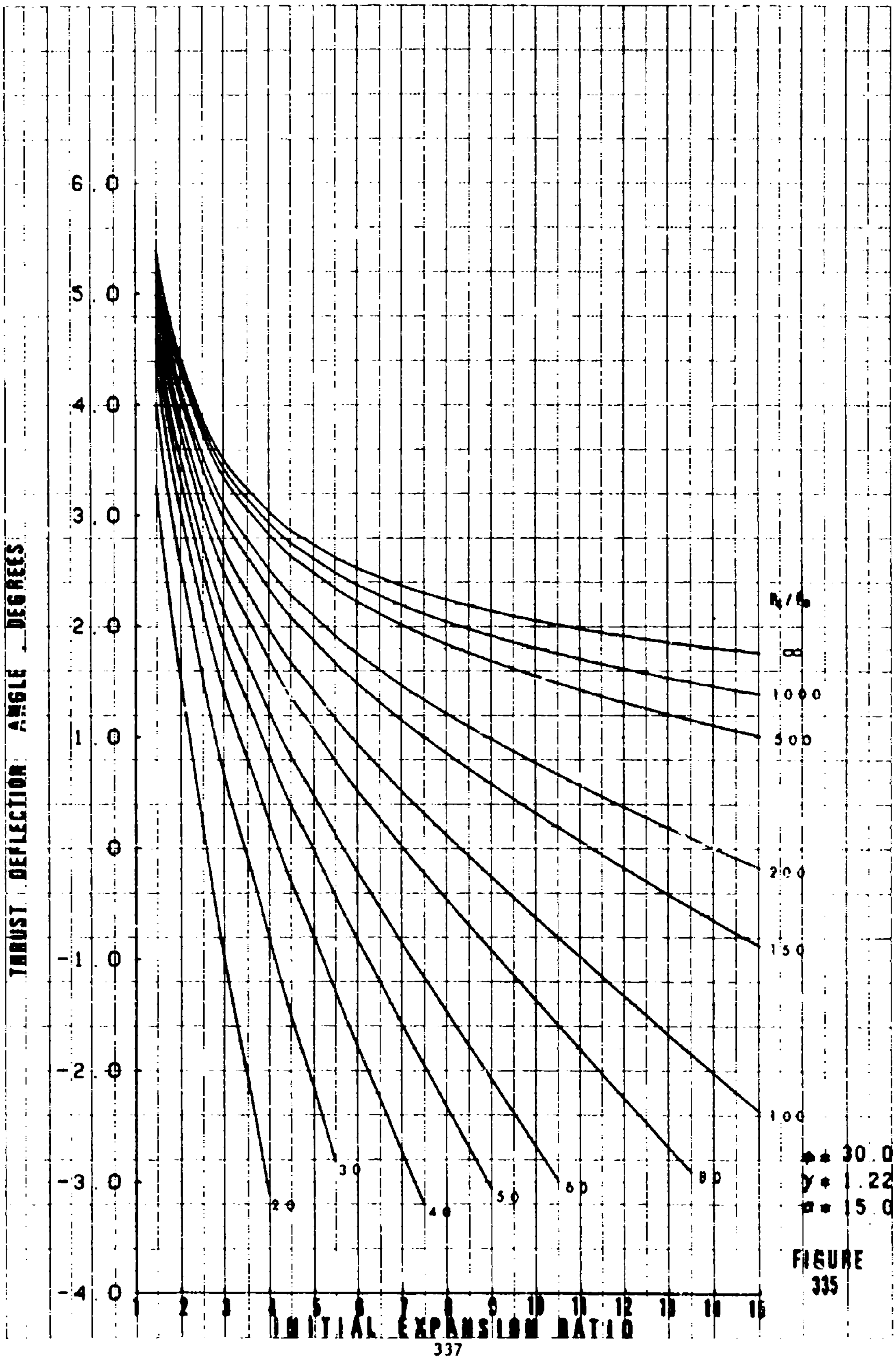
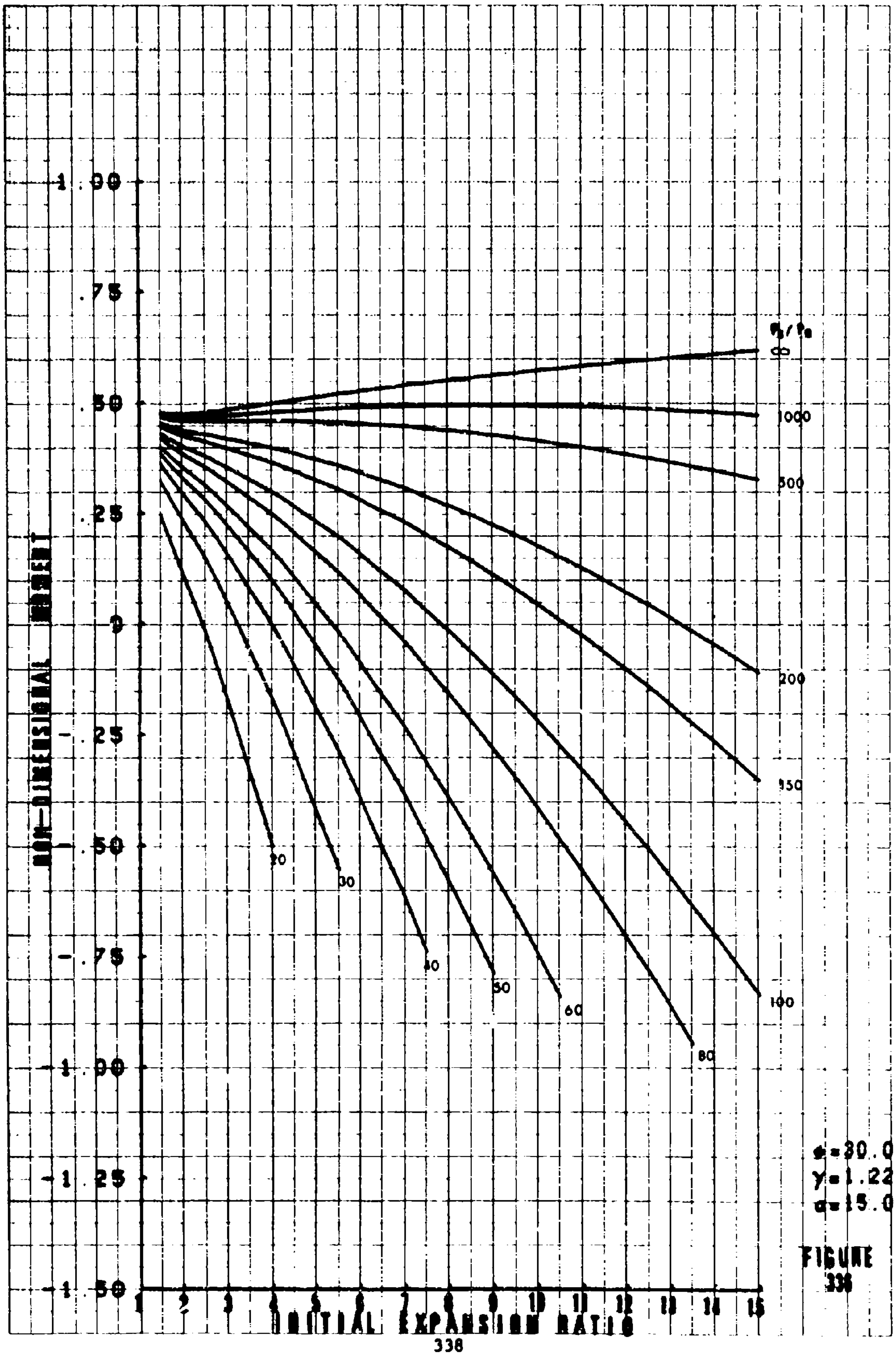
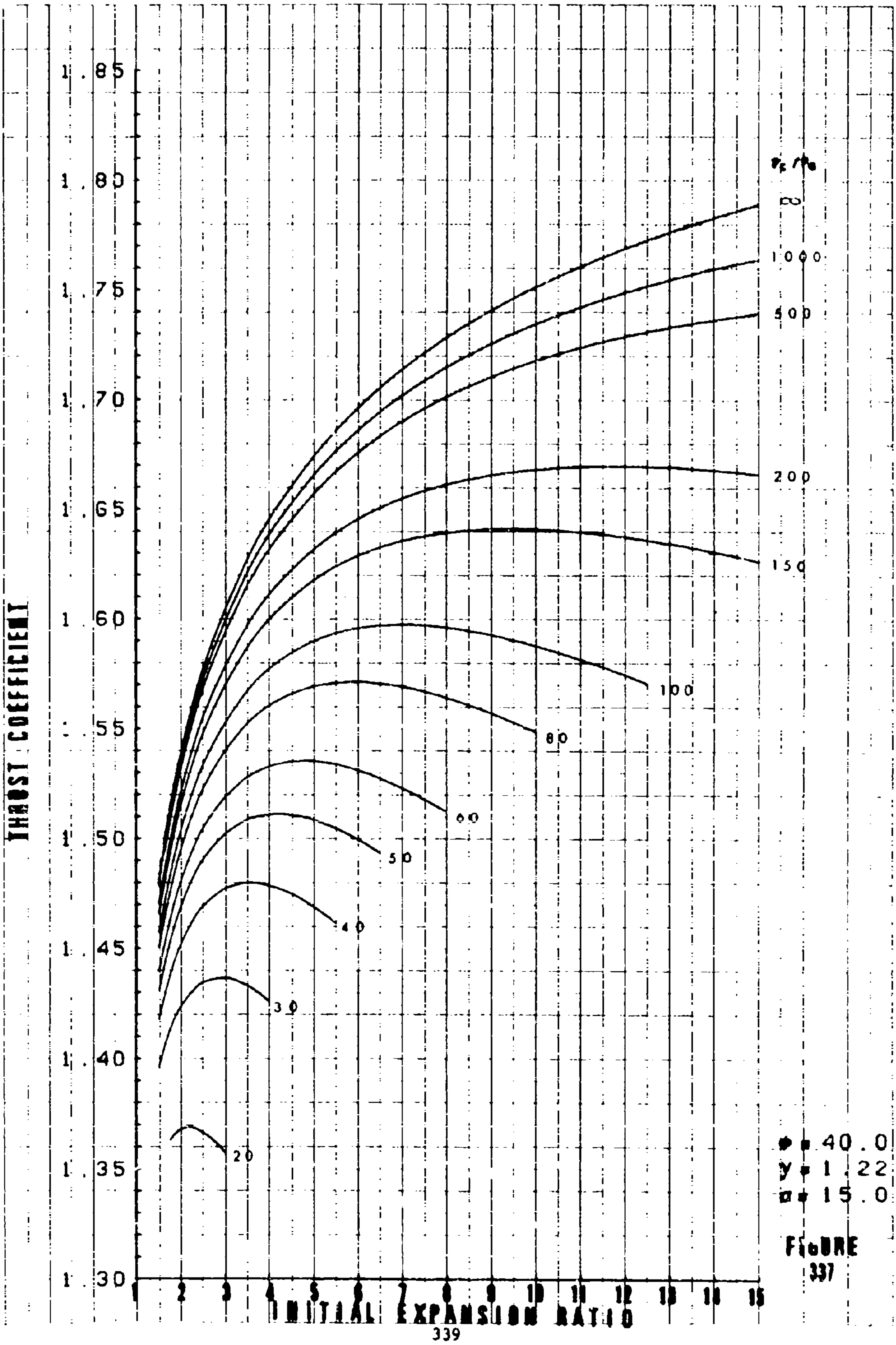

THRUST DEFLECTION ANGLE , DEGREES
6.0
5.0
4.0
3.0
2.0
1.0
0
-1.0
-2.0
-3.0
-4.0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
INITIAL EXPANSION RATIO
∞
1000
500
200
150
100
80
60
50
40
30
20
φ = 30.0
γ = 1.22
α = 15.0

FIGURE 335



NON-DIMENSIONAL MOMENT
1.00
.75
.50
.25
0
-.25
-.50
-.75
-1.00
-1.25
-1.50
INITIAL EXPANSION RATIO
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
P_3/P_a
∞
1000
500
200
150
100
80
60
50
40
30
20
ϕ=30.0
γ=1.22
α=15.0

FIGURE 338


THRUST COEFFICIENT
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
INITIAL EXPANSION RATIO
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
P_c/P_a
∞
1000
500
200
150
100
80
60
50
40
30
20
ϕ = 40.0
γ = 1.22
α = 15.0
FIGURE 337

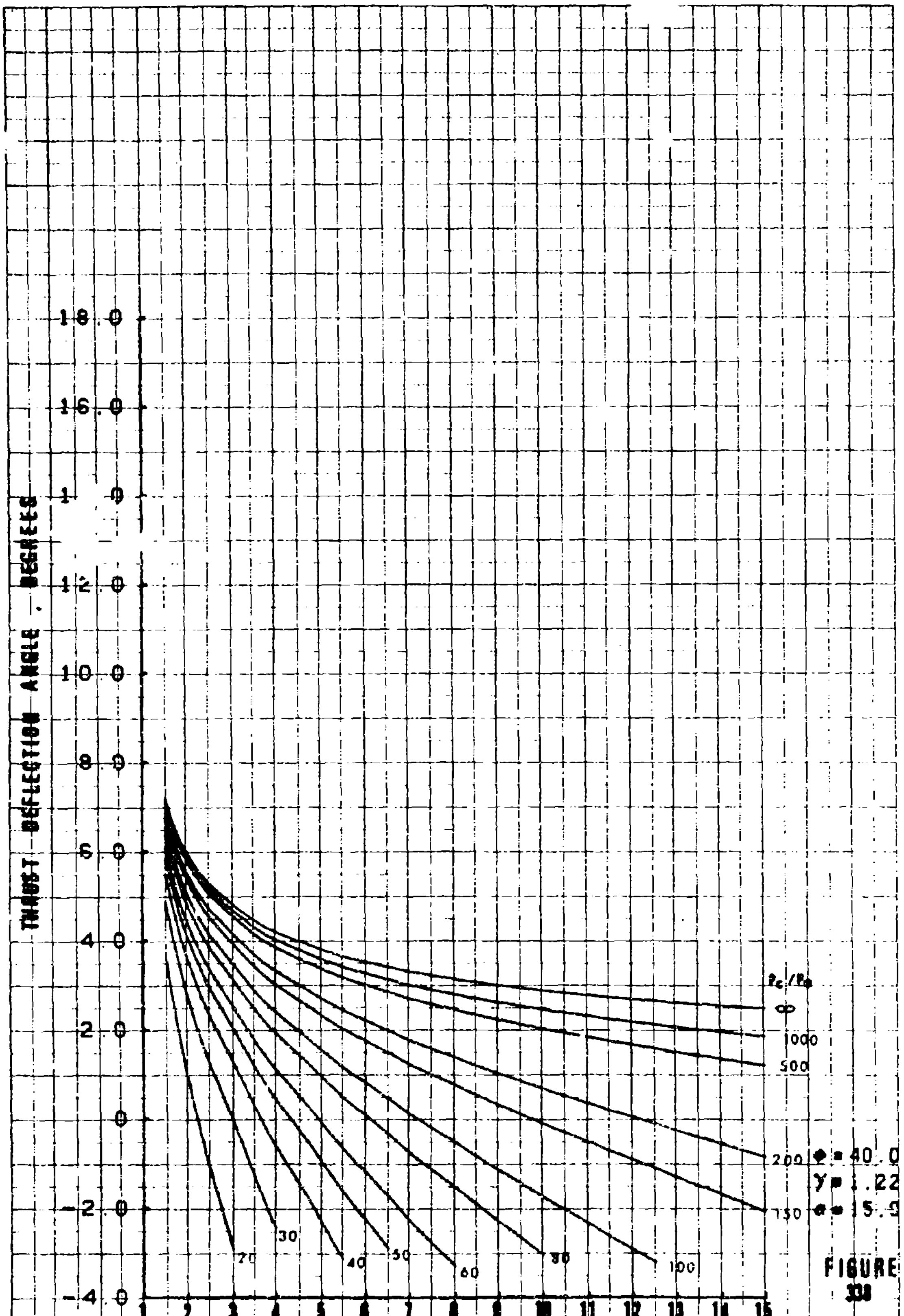
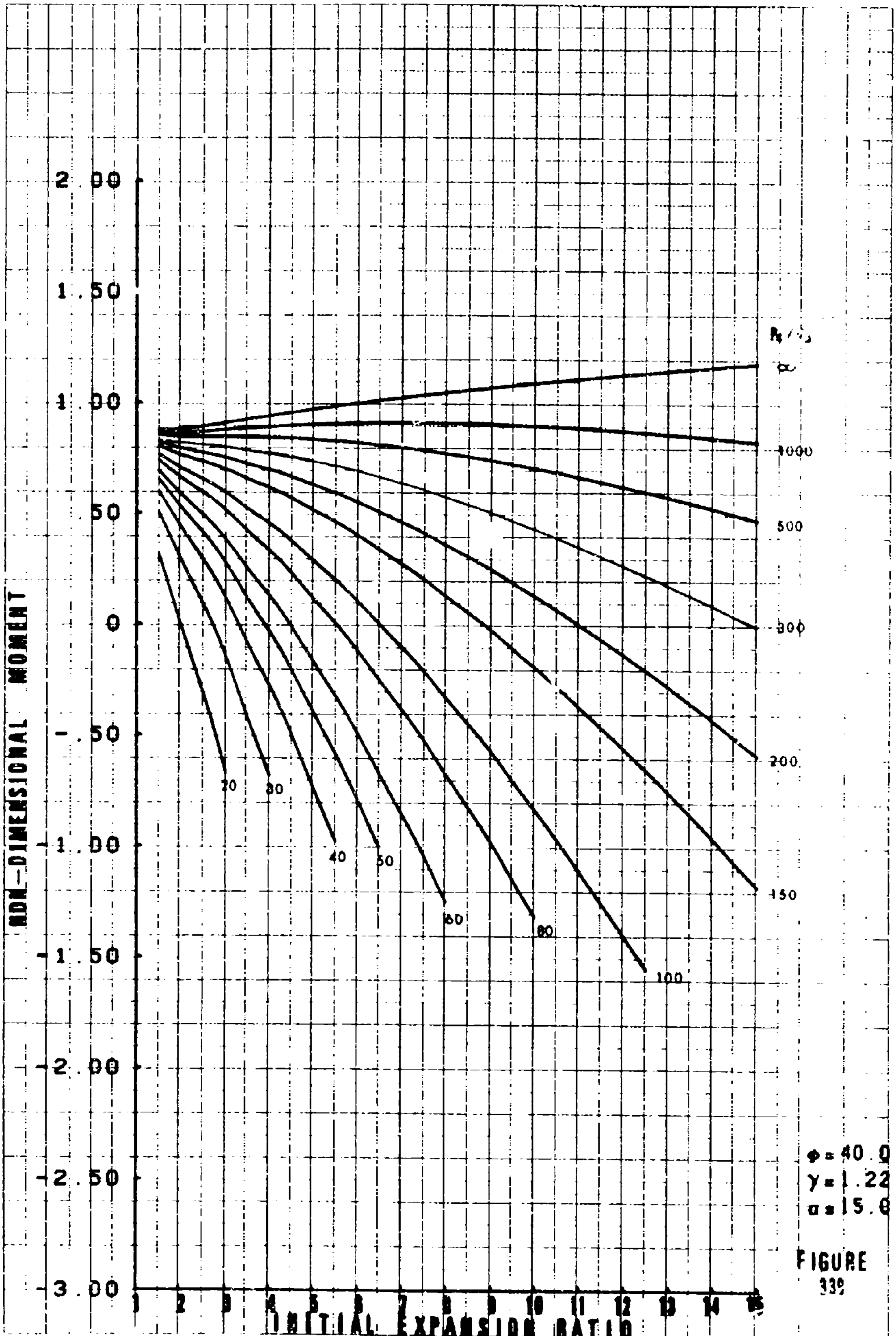

18.0
16.0
1 .0
12.0
10.0
8.0
6.0
4.0
2.0
0
-2.0
-4.0
THRUST DEFLECTION ANGLE — DEGREES
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
INITIAL EXPANSION RATIO
Pc/Pa
∞
1000
500
200
150
100
80
60
50
40
30
20
φ = 40.0
γ = 1.22
α = 15.0

FIGURE 338



2.00
1.50
1.00
.50
0
-.50
-1.00
-1.50
-2.00
-2.50
-3.00
NON-DIMENSIONAL MOMENT
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
INITIAL EXPANSION RATIO
∞
1000
500
300
200
150
20
30
40
50
60
80
100
$\phi = 40.0$
$\gamma = 1.22$
$\alpha = 15.0$

FIGURE 339

1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
THRUST COEFFICIENT
INITIAL EXPANSION RATIO
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
∞
1000
500
200
150
100
80
60
50
40
30
20
45.0
1.22
15.0

FIGURE 340

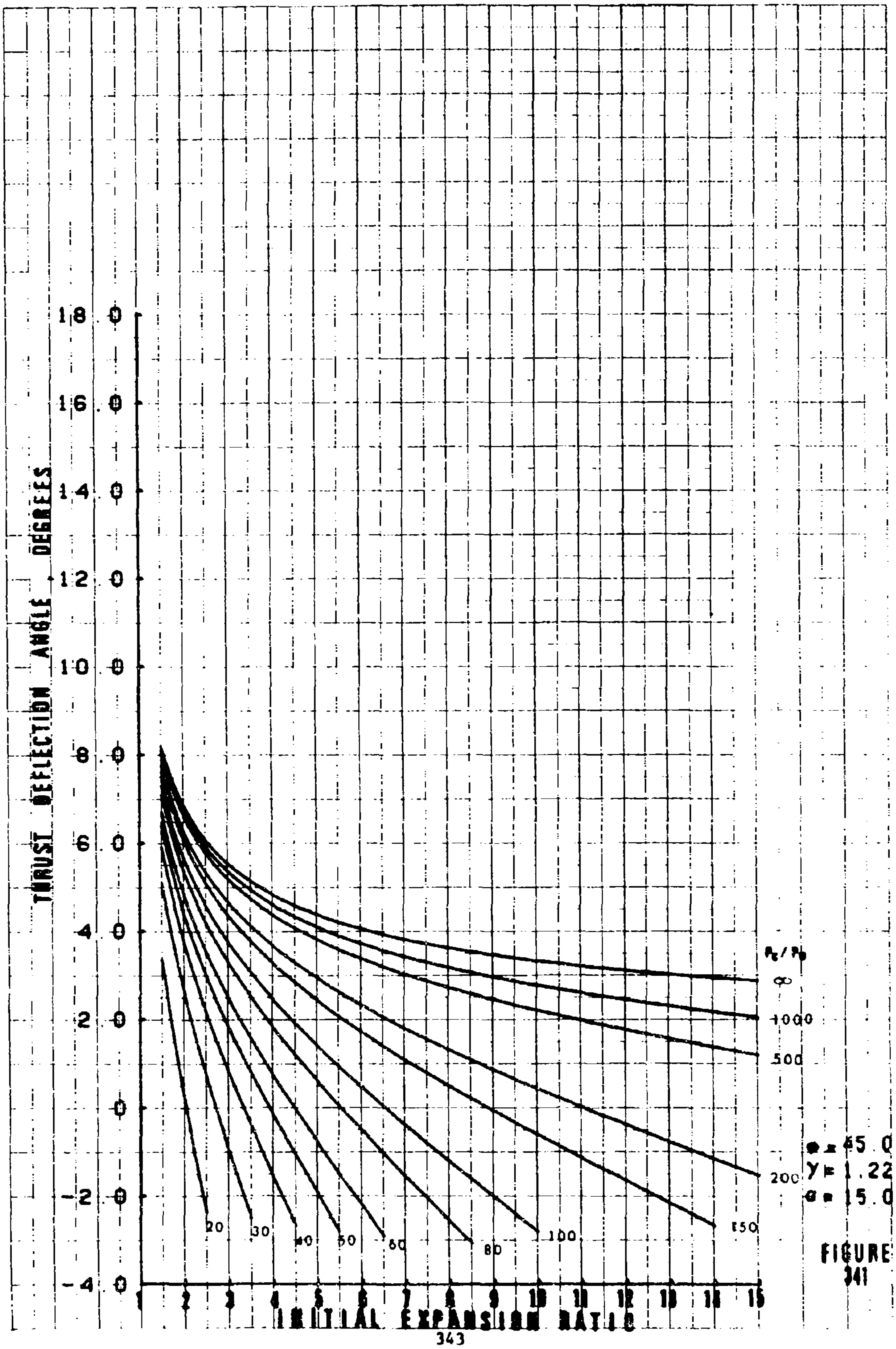
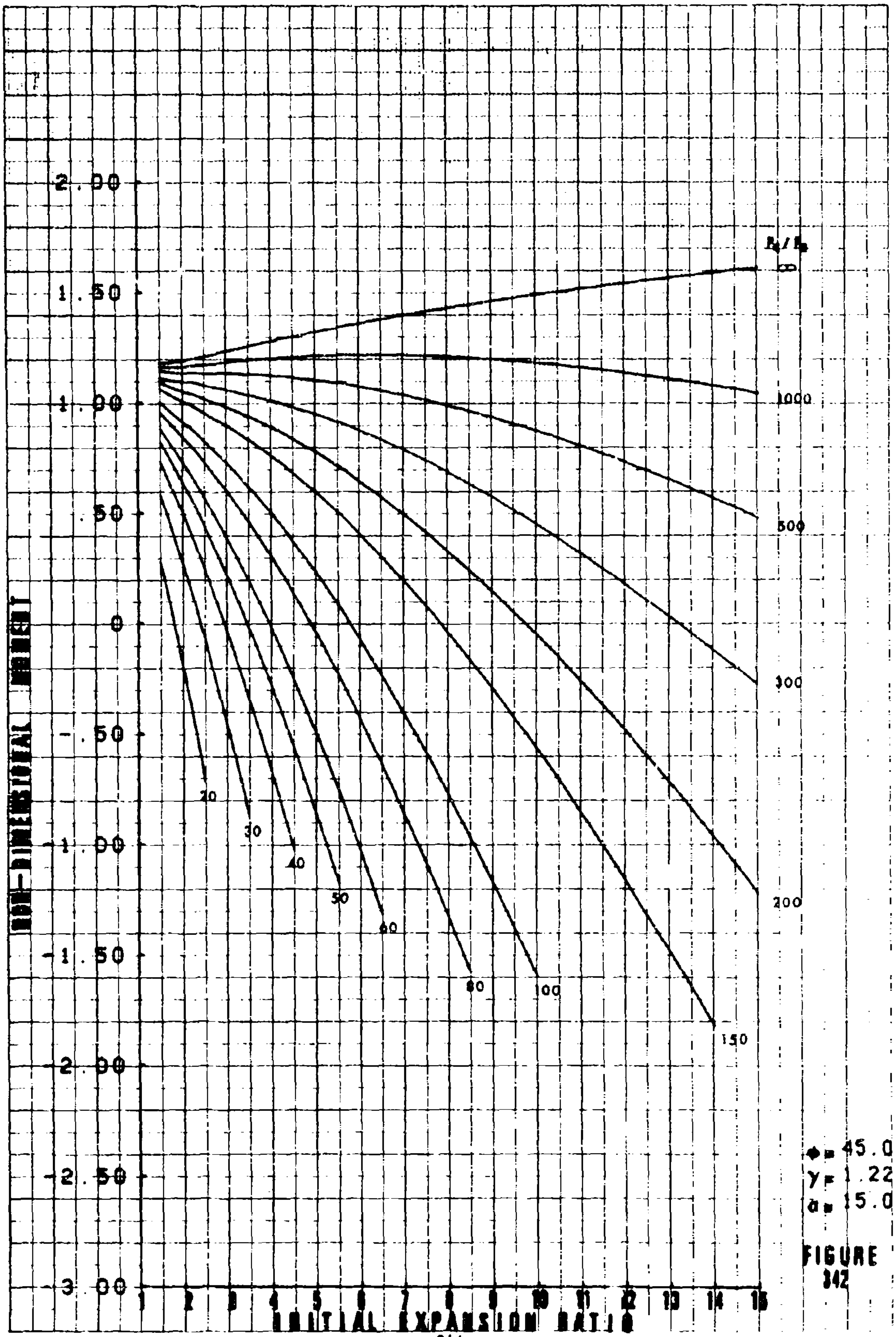

THRUST DEFLECTION ANGLE DEGREES
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0
-2.0
-4.0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
∞
1000
500
200
150
100
80
60
50
40
30
20

FIGURE 341



NON-DIMENSIONAL MOMENT
2.00
1.50
1.00
.50
0
-.50
-1.00
-1.50
-2.00
-2.50
-3.00
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
P_c/P_a
∞
1000
500
300
200
150
100
80
60
50
40
30
20
ϕ = 45.0
γ = 1.22
α = 15.0

FIGURE 342

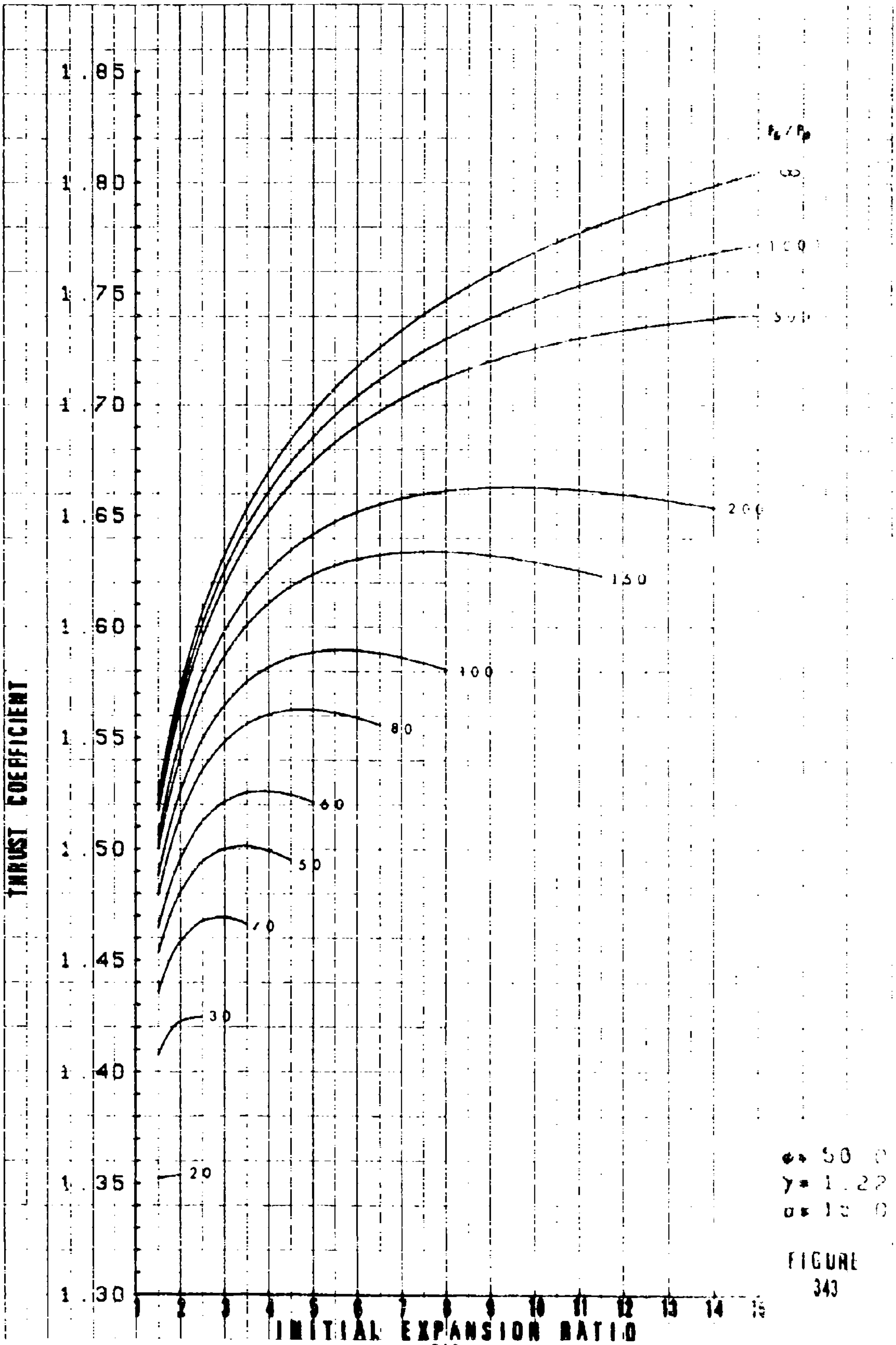

THRUST COEFFICIENT
INITIAL EXPANSION RATIO
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
P_c/P_p
∞
1000
500
200
150
100
80
60
50
40
30
20
φ = 50.0
γ = 1.22
α = 15.0

FIGURE 343

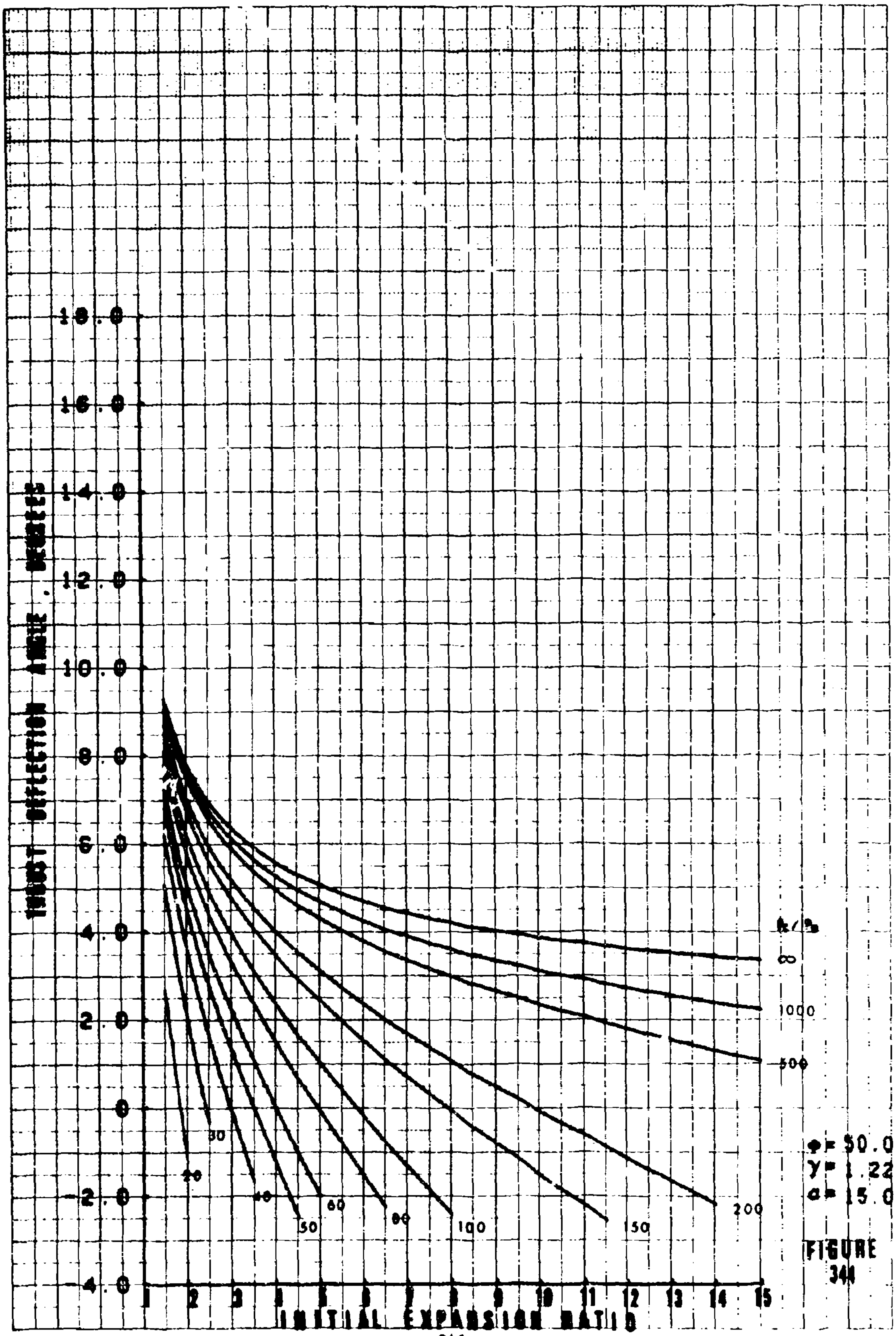
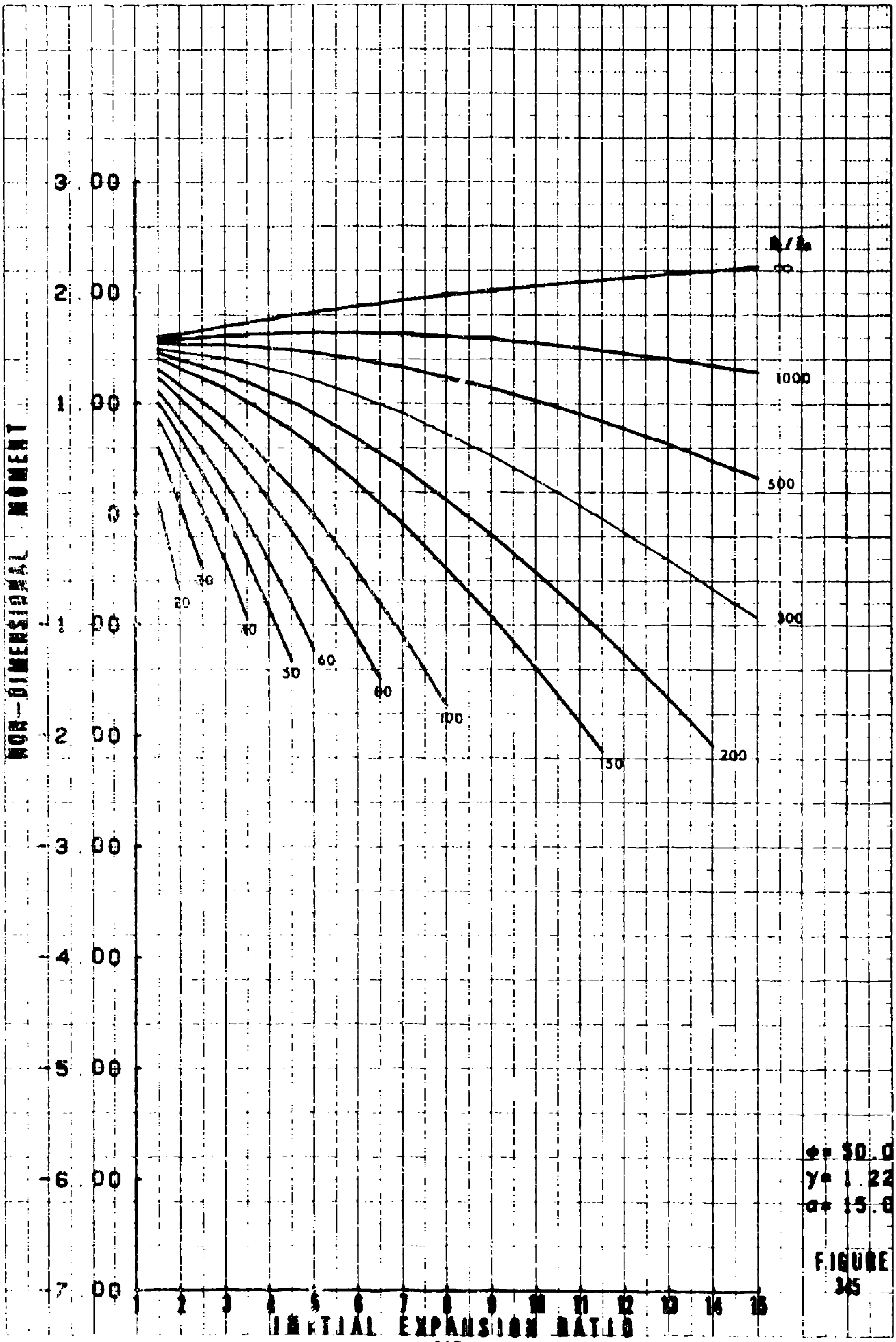

THRUST DEFLECTION ANGLE, DEGREES
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0
-2.0
-4.0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
INITIAL EXPANSION RATIO
∞
1000
500
200
150
100
80
60
50
40
30
20
φ= 50.0
γ= 1.22
α= 15.0

FIGURE 341


NON-DIMENSIONAL MOMENT
3.00
2.00
1.00
0
-1.00
-2.00
-3.00
-4.00
-5.00
-6.00
-7.00
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
INITIAL EXPANSION RATIO
∞
1000
500
300
200
150
100
80
60
50
40
30
20

THRUST COEFFICIENT
INITIAL EXPANSION RATIO
P_c/P_a
∞
1000
300
200
150
100
80
60
50
40
30
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
ϕ= 55.0
γ= 1.22
α= 15.0

FIGURE 348

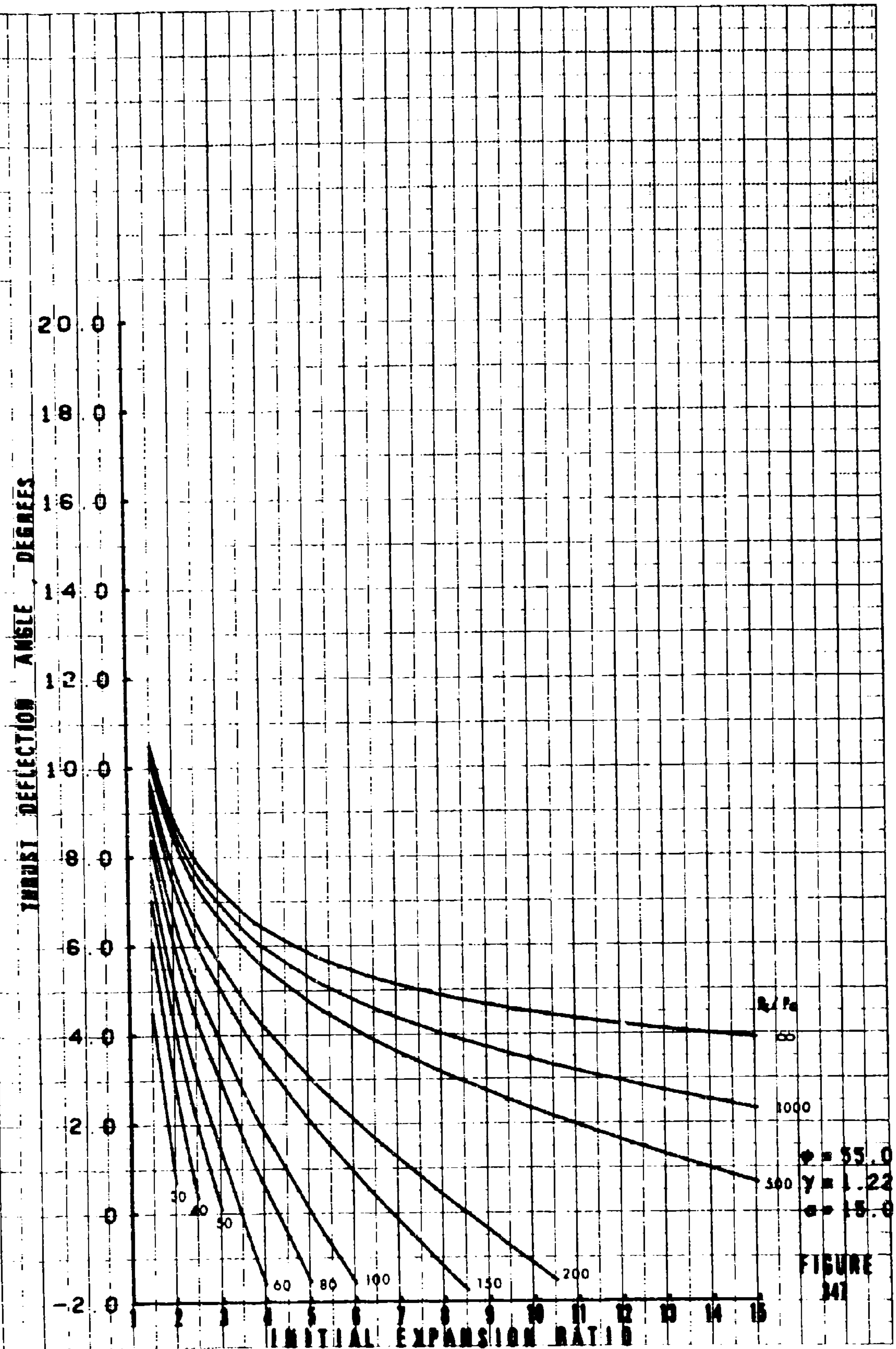
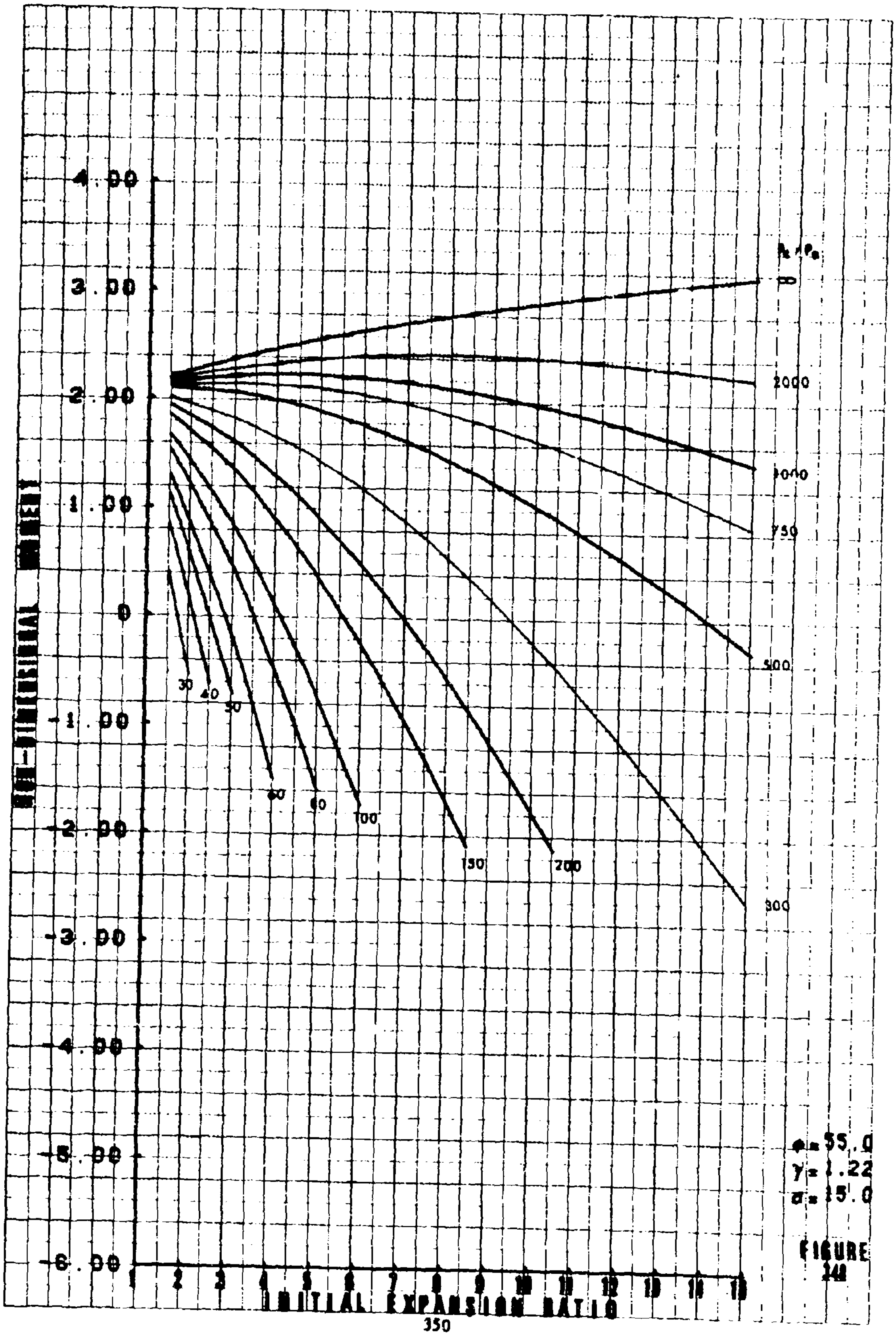
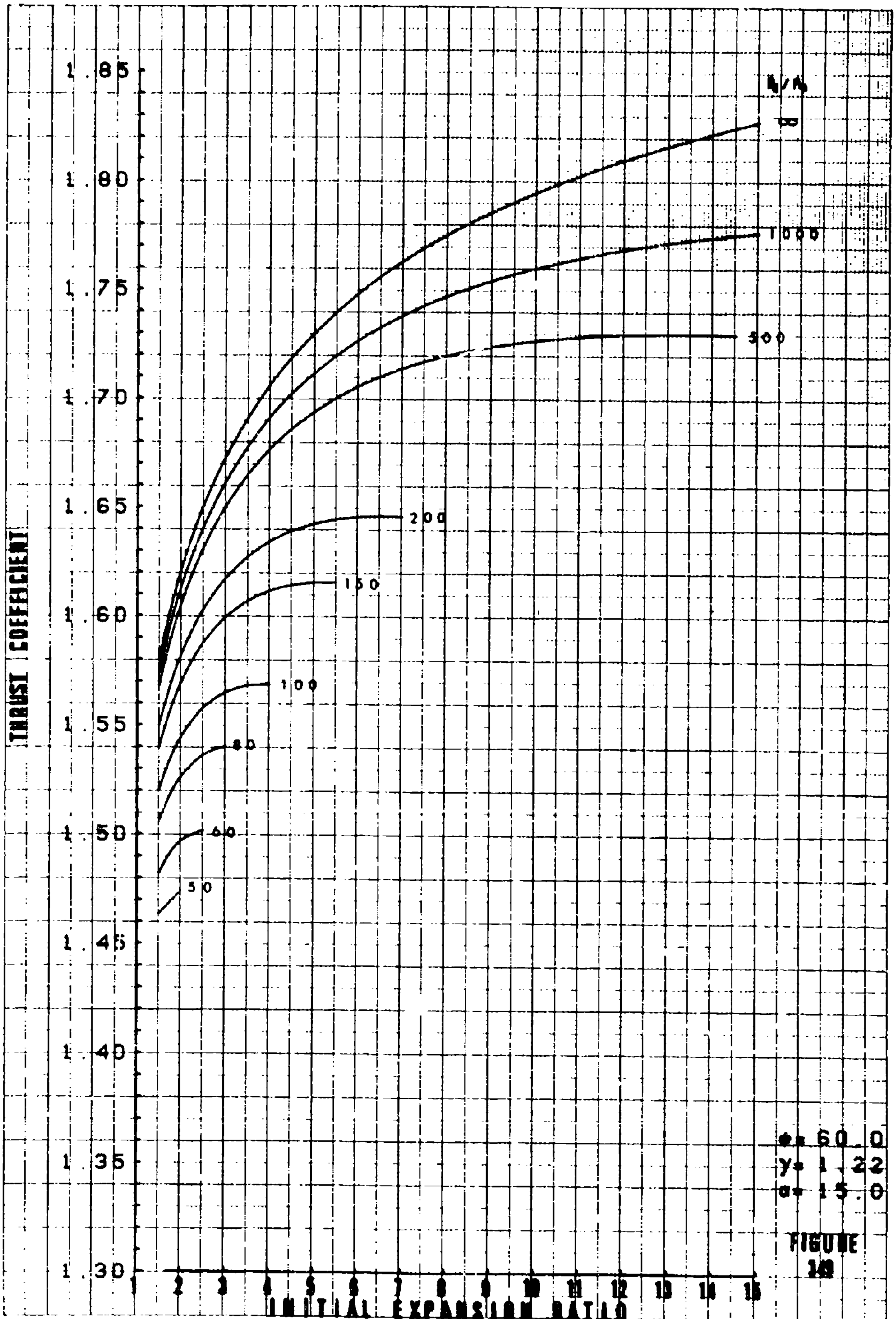
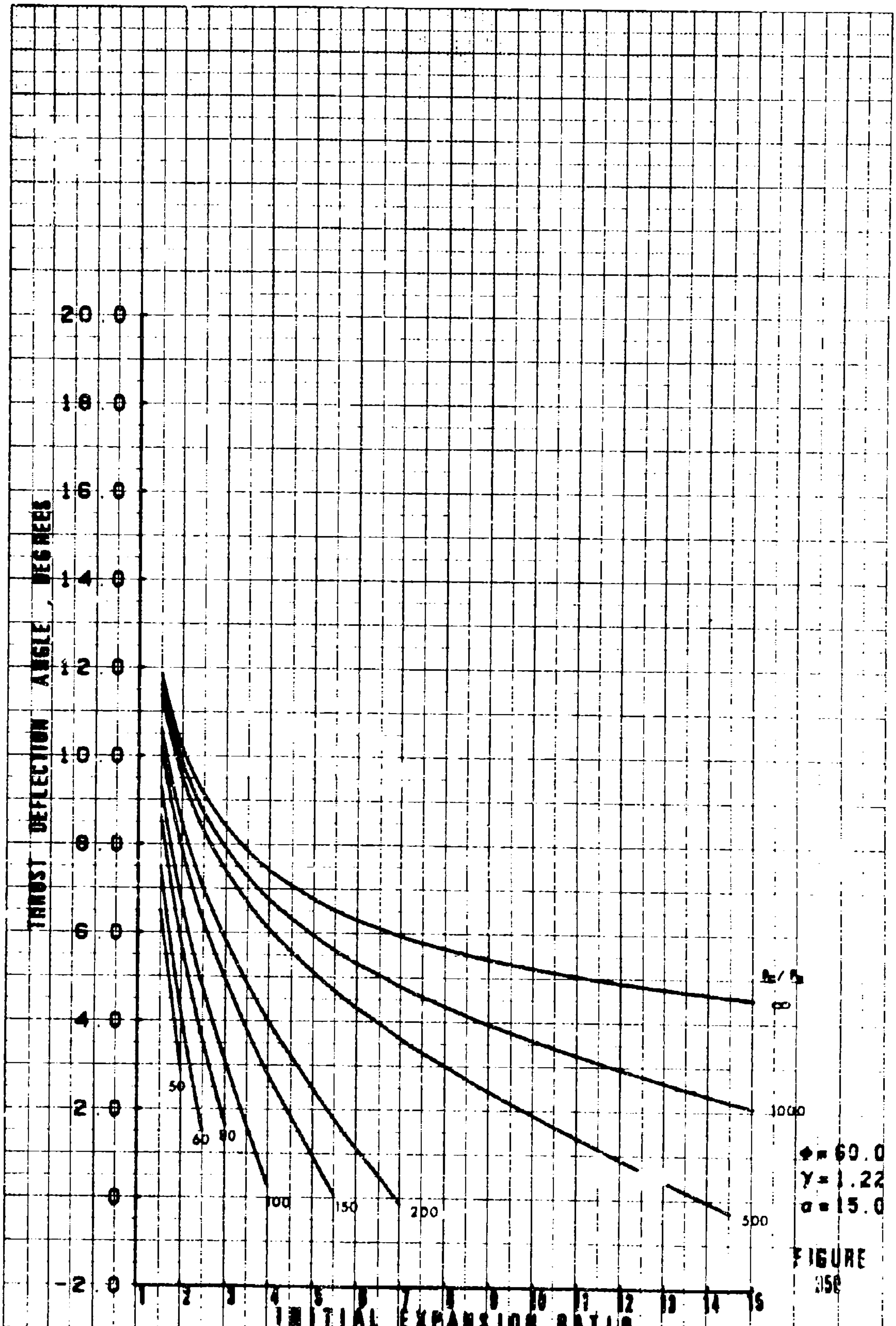

THRUST DEFLECTION ANGLE DEGREES
20.0
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0
-2.0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
30
40
50
60
80
100
150
200
500
1000
∞
P_c/P_a
ϕ = 55.0
γ = 1.22
ϵ = 15.0

FIGURE 347


4.00
3.00
2.00
1.00
0
-1.00
-2.00
-3.00
-4.00
-5.00
-6.00
NON-DIMENSIONAL MOMENT
INITIAL EXPANSION RATIO
30
40
50
60
80
100
150
200
300
500
750
1000
2000
ϕ = 55.0
γ = 1.22
σ = 15.0
FIGURE 248


THRUST COEFFICIENT
INITIAL EXPANSION RATIO
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
∞
1000
500
200
150
100
80
60
50
φ= 60.0
γ= 1.22
α= 15.0
FIGURE



THRUST DEFLECTION ANGLE, DEGREES
20.0
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0
-2.0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
50
60
80
100
150
200
500
1000
∞
Φ = 60.0
γ = 1.22
α = 15.0

FIGURE 358

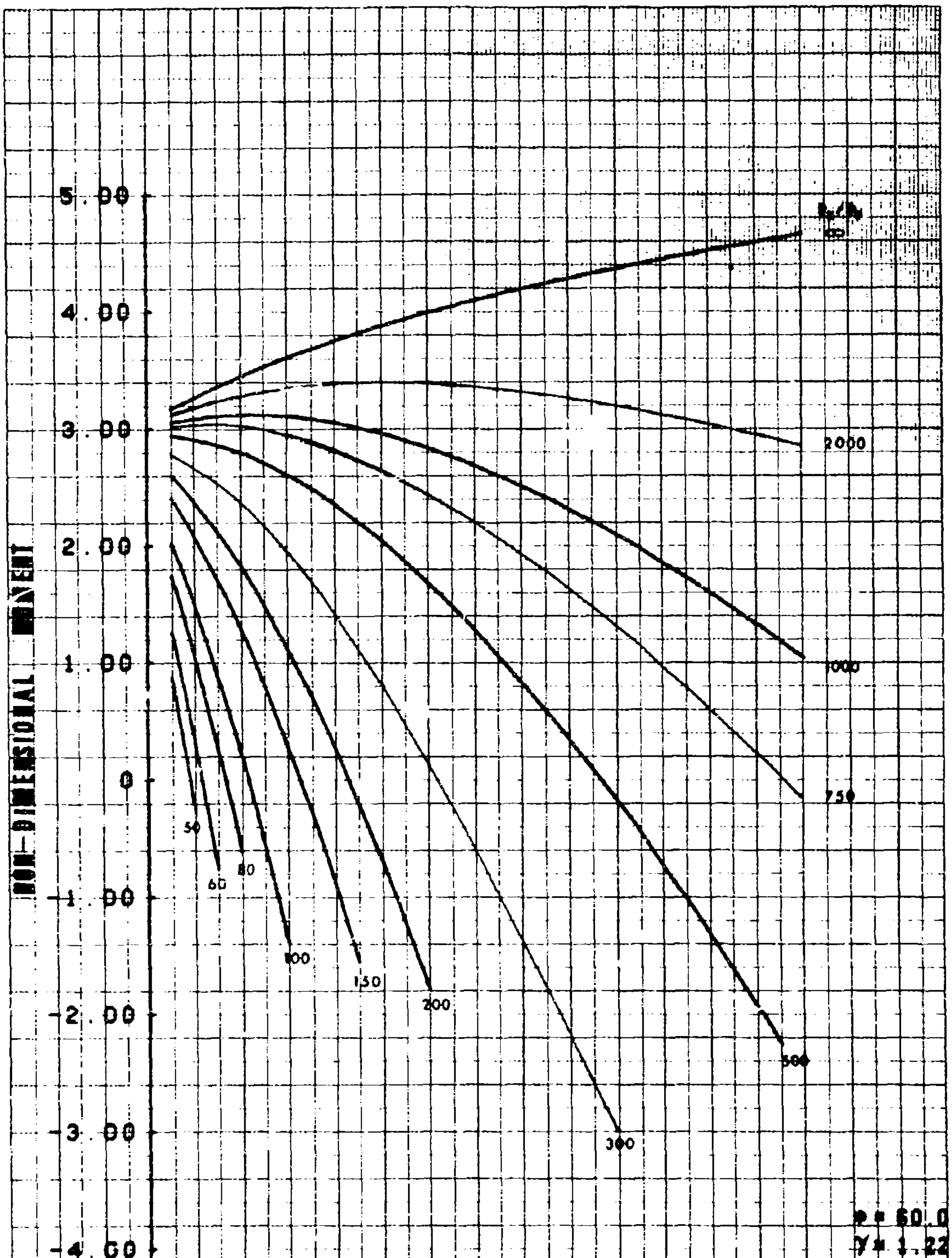

NON-DIMENSIONAL MOMENT
5.00
4.00
3.00
2.00
1.00
0
-1.00
-2.00
-3.00
-4.00
-5.00
INITIAL EXPANSION RATIO
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
2000
1000
750
500
300
200
150
100
80
60
50
γ = 1.22

FIGURE 351

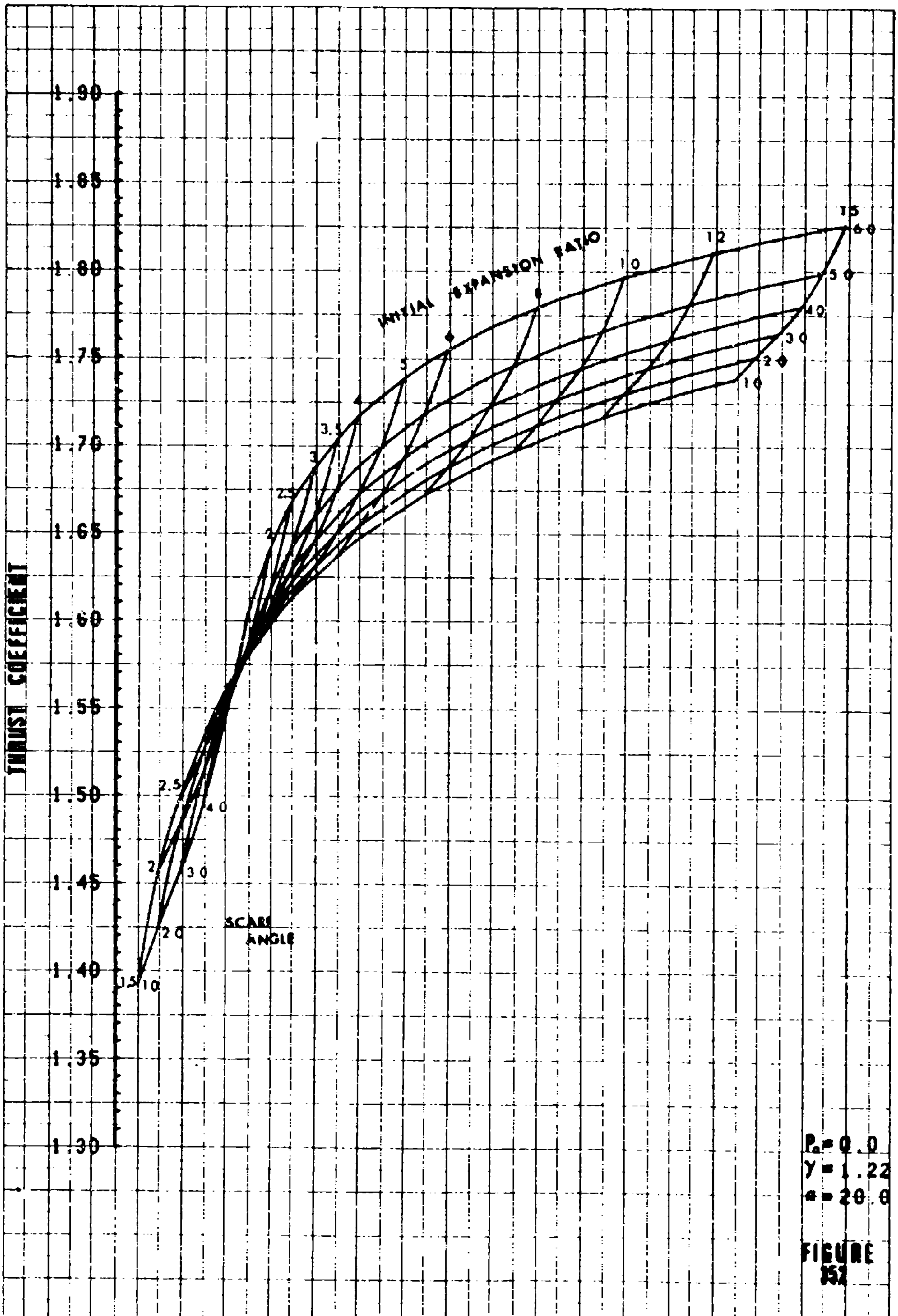
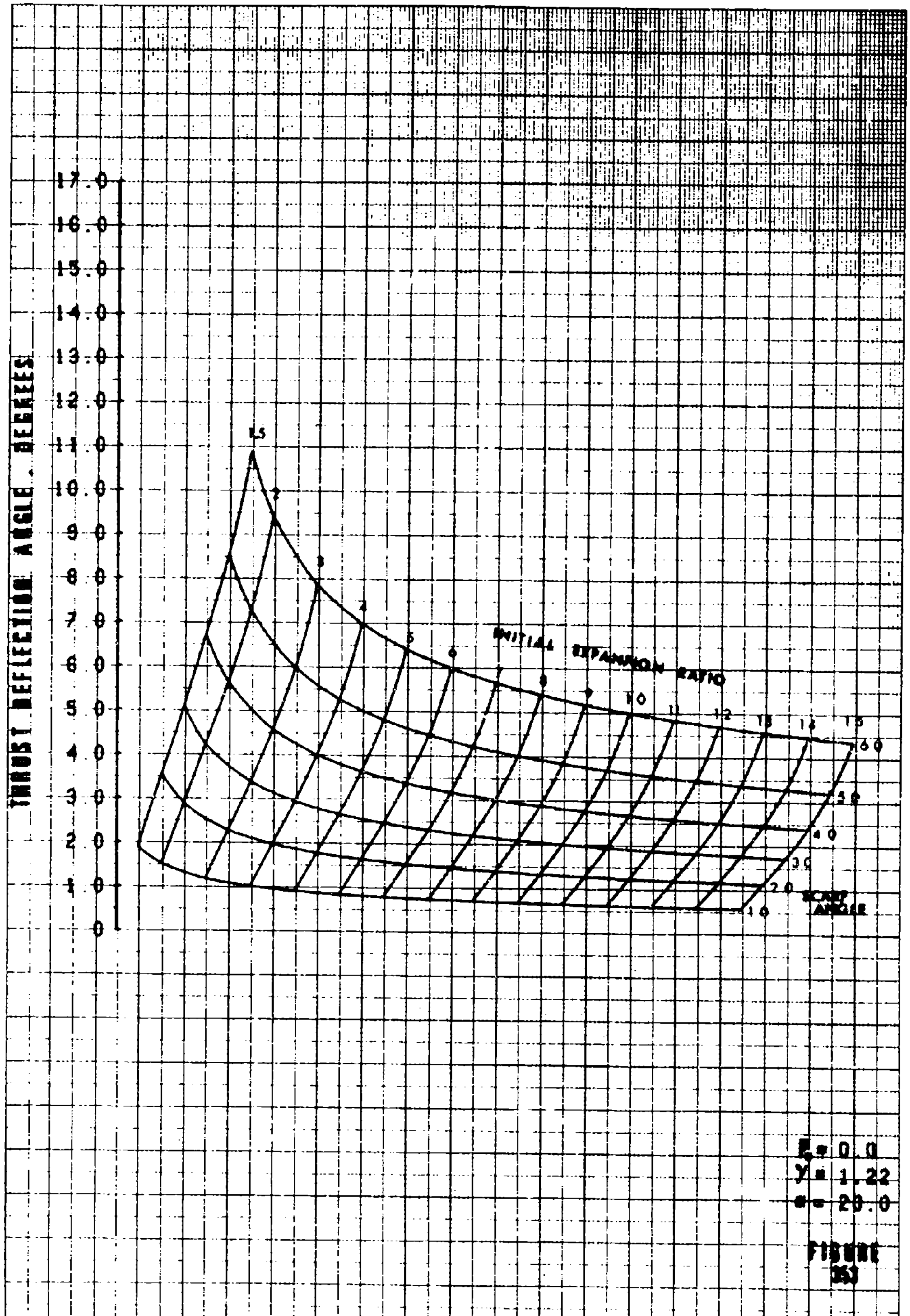

THRUST COEFFICIENT
1.90
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
INITIAL EXPANSION RATIO
SCARF ANGLE
15
12
10
8
6
5
4
3.5
3
2.5
2
1.5
60
50
40
30
20
10
$P_a = 0.0$
$\gamma = 1.22$
$\alpha = 20.0$

FIGURE 352


THRUST DEFLECTION ANGLE , DEGREES
17.0
16.0
15.0
14.0
13.0
12.0
11.0
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
INITIAL EXPANSION RATIO
SCARF ANGLE
Y = 1.22
FIGURE
353

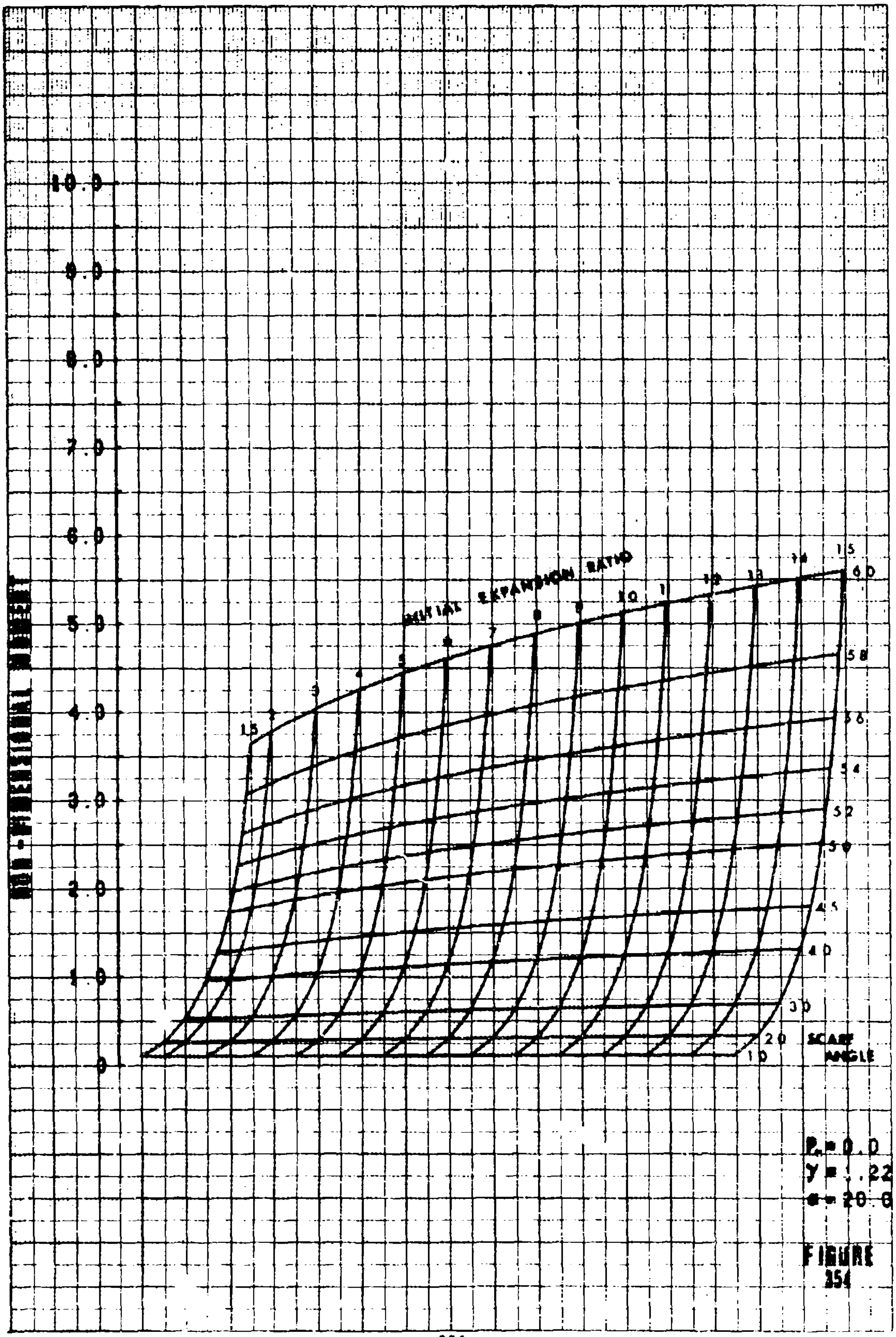
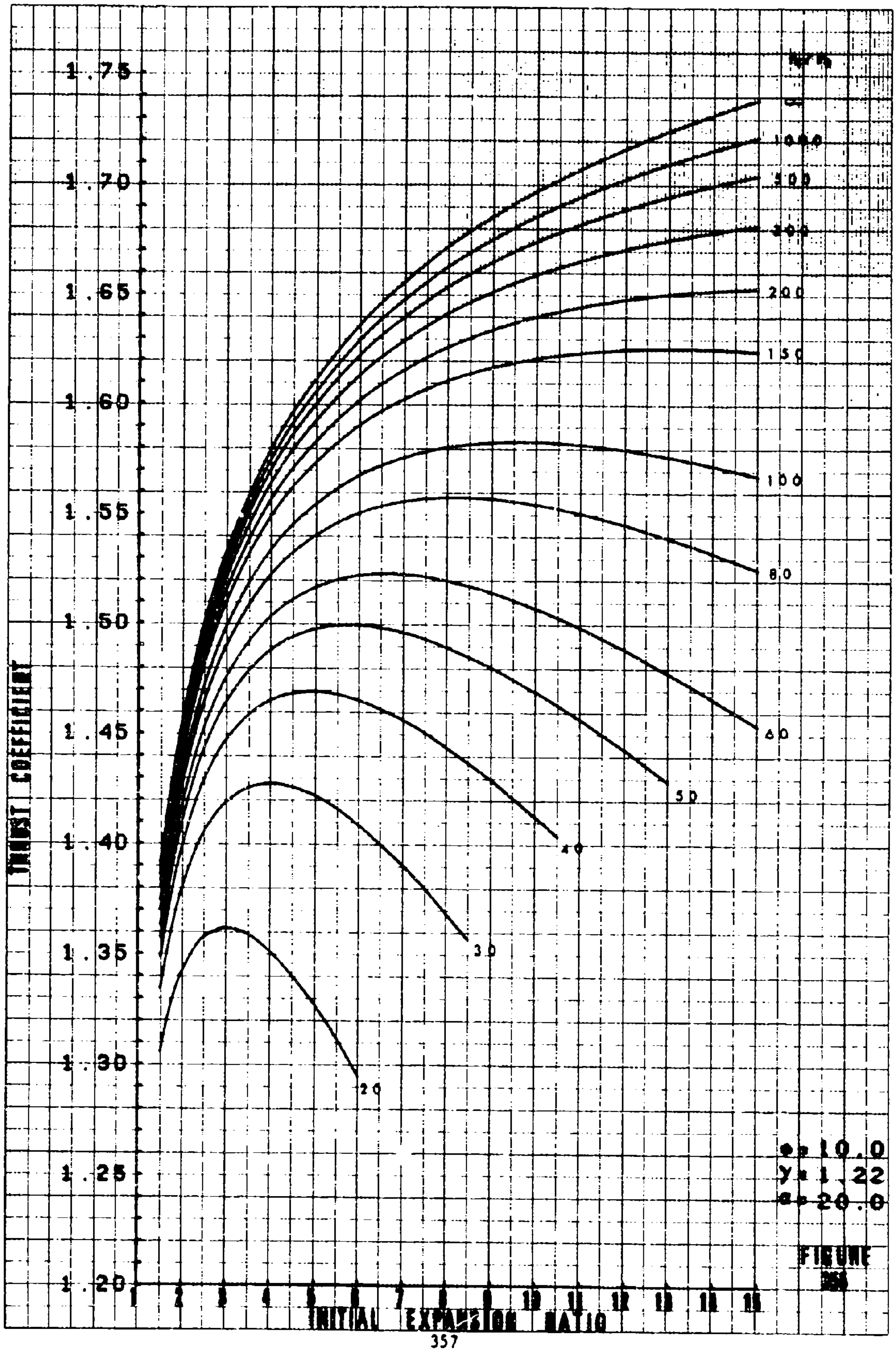
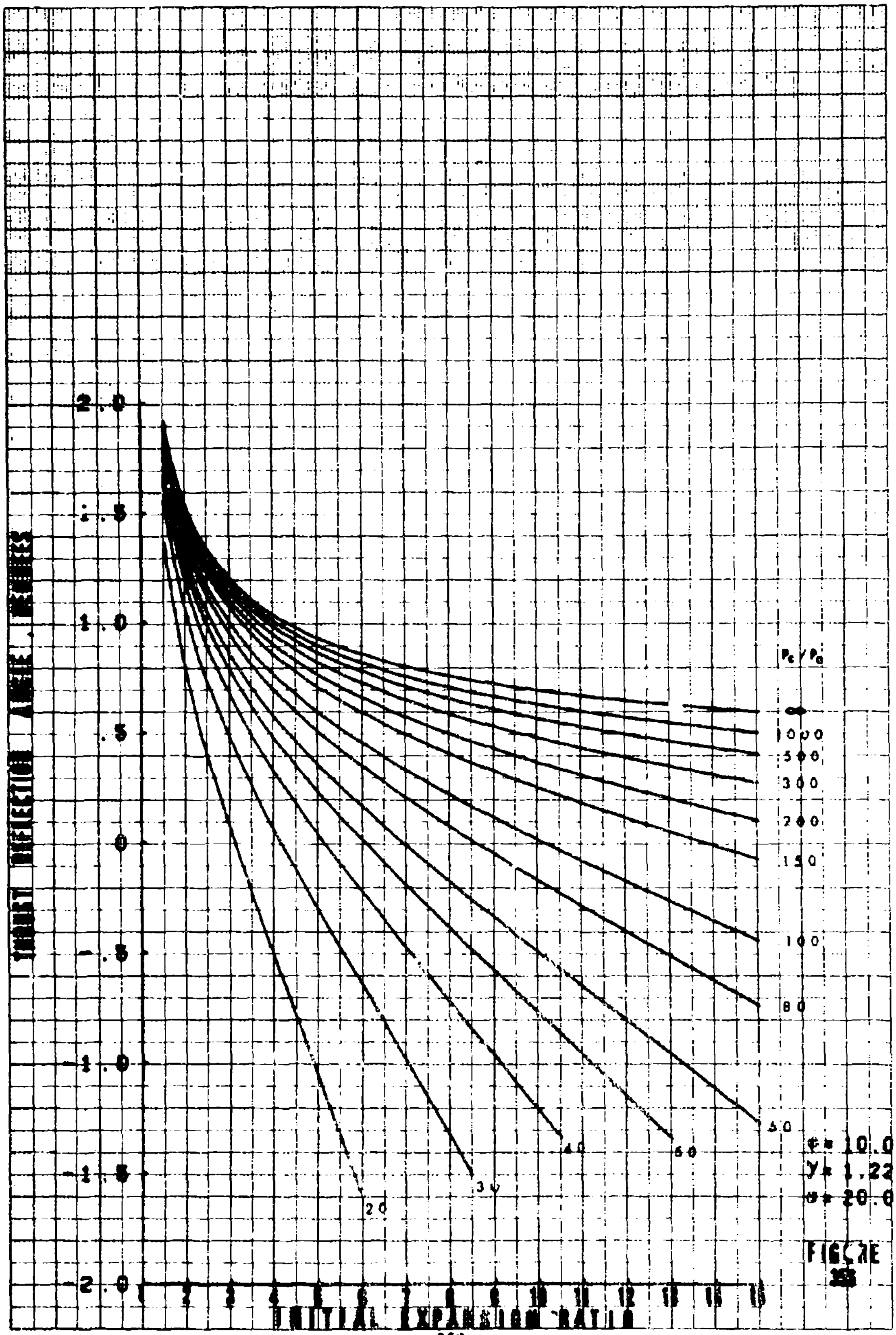
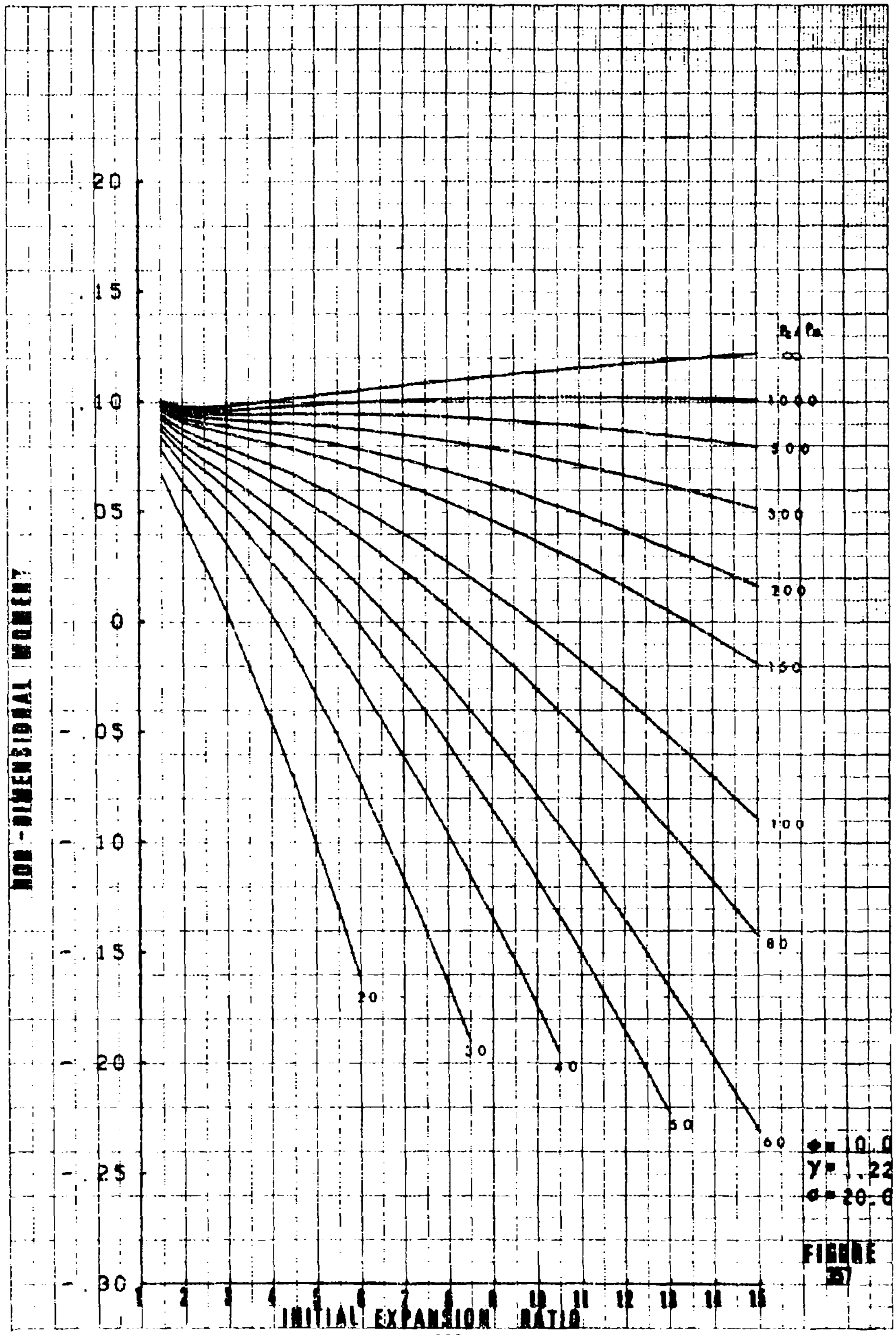

10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
INITIAL EXPANSION RATIO
SCARF ANGLE

FIGURE 354


THRUST COEFFICIENT
INITIAL EXPANSION RATIO
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
1.25
1.20
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
∞
1000
500
300
200
150
100
80
60
50
40
30
20
γ = 1.22
FIGURE



THRUST DEFLECTION ANGLE, DEGREES
2.0
1.5
1.0
.5
0
-.5
-1.0
-1.5
-2.0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
INITIAL EXPANSION RATIO
P_c / P_a
∞
1000
500
300
200
150
100
80
40
30
20
1.22
FIGURE



NON-DIMENSIONAL MOMENT
.20
.15
.10
.05
0
-.05
-.10
-.15
-.20
-.25
-.30
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
P_2/P_m
∞
1000
500
300
200
150
100
80
60
50
40
30
20
ϕ = 10.0
γ = 1.22
σ = 20.0
FIGURE

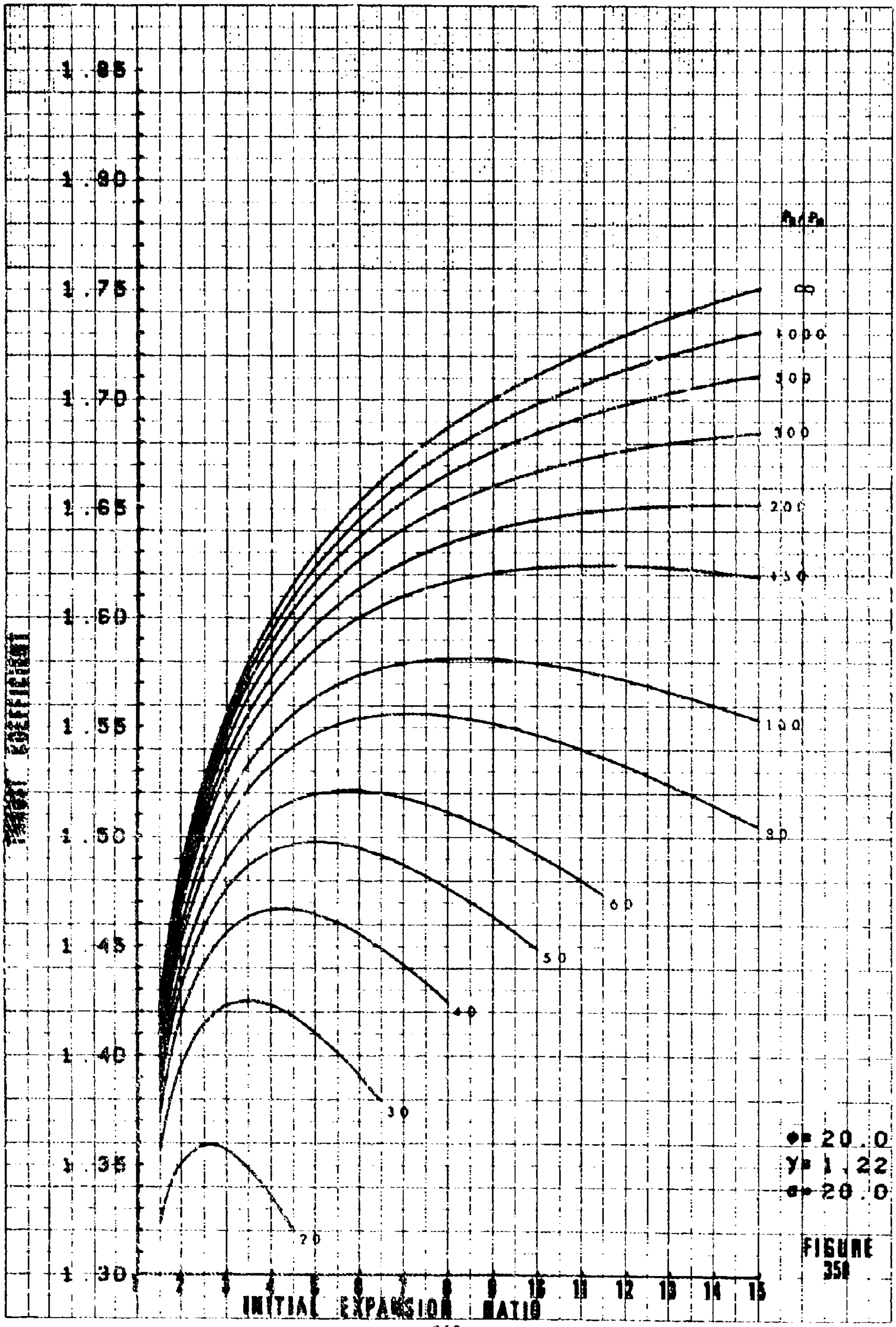
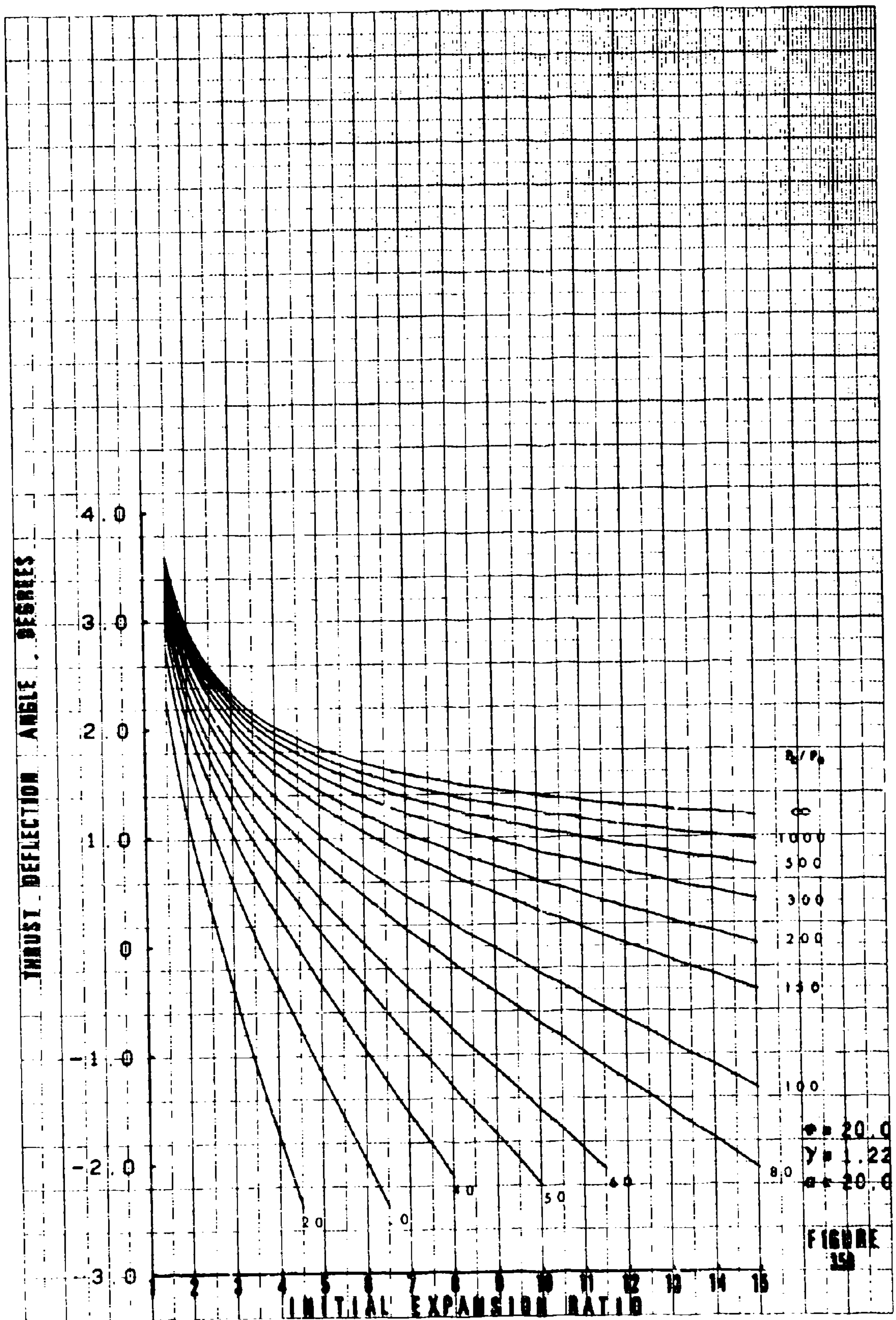
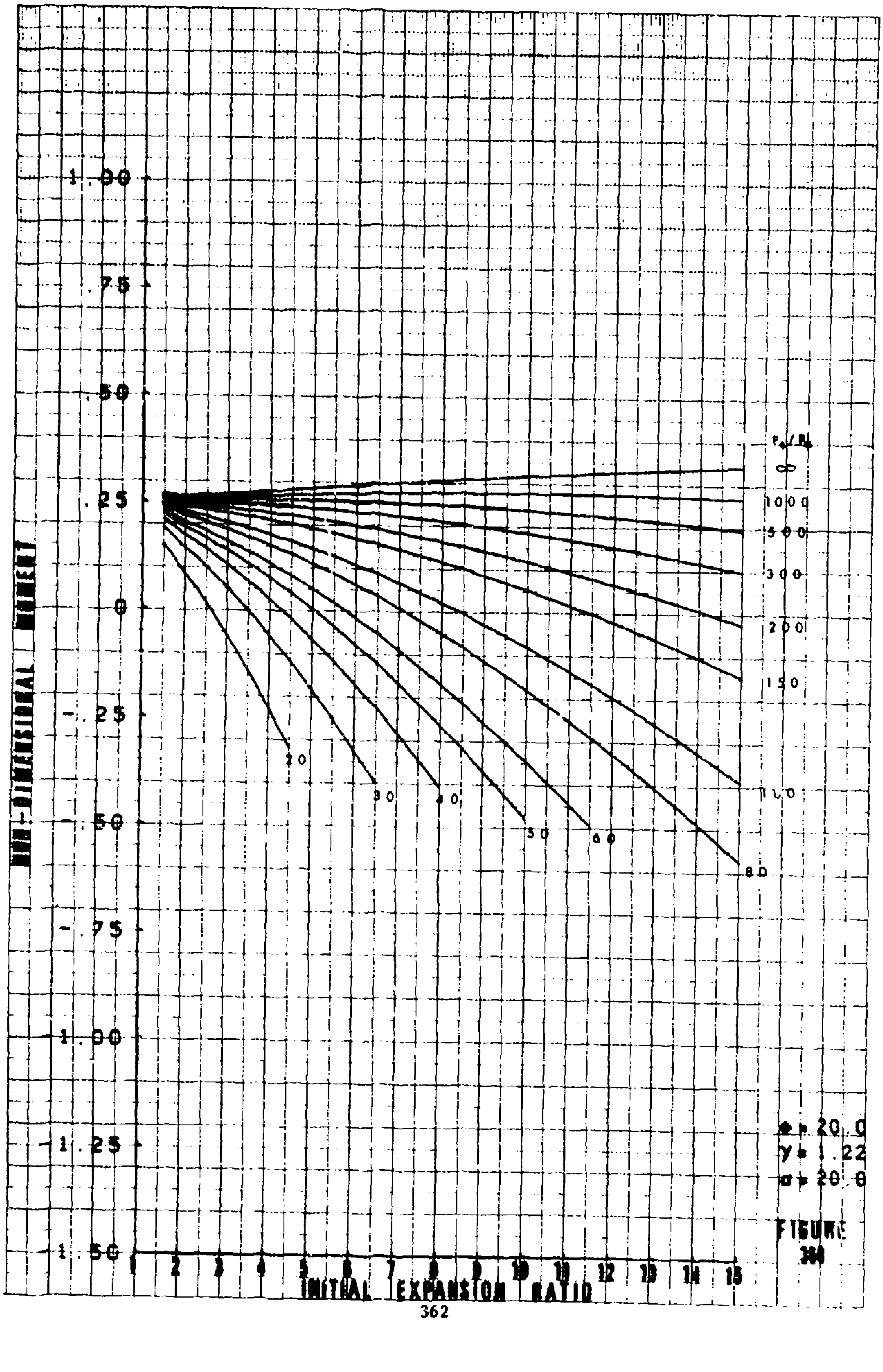
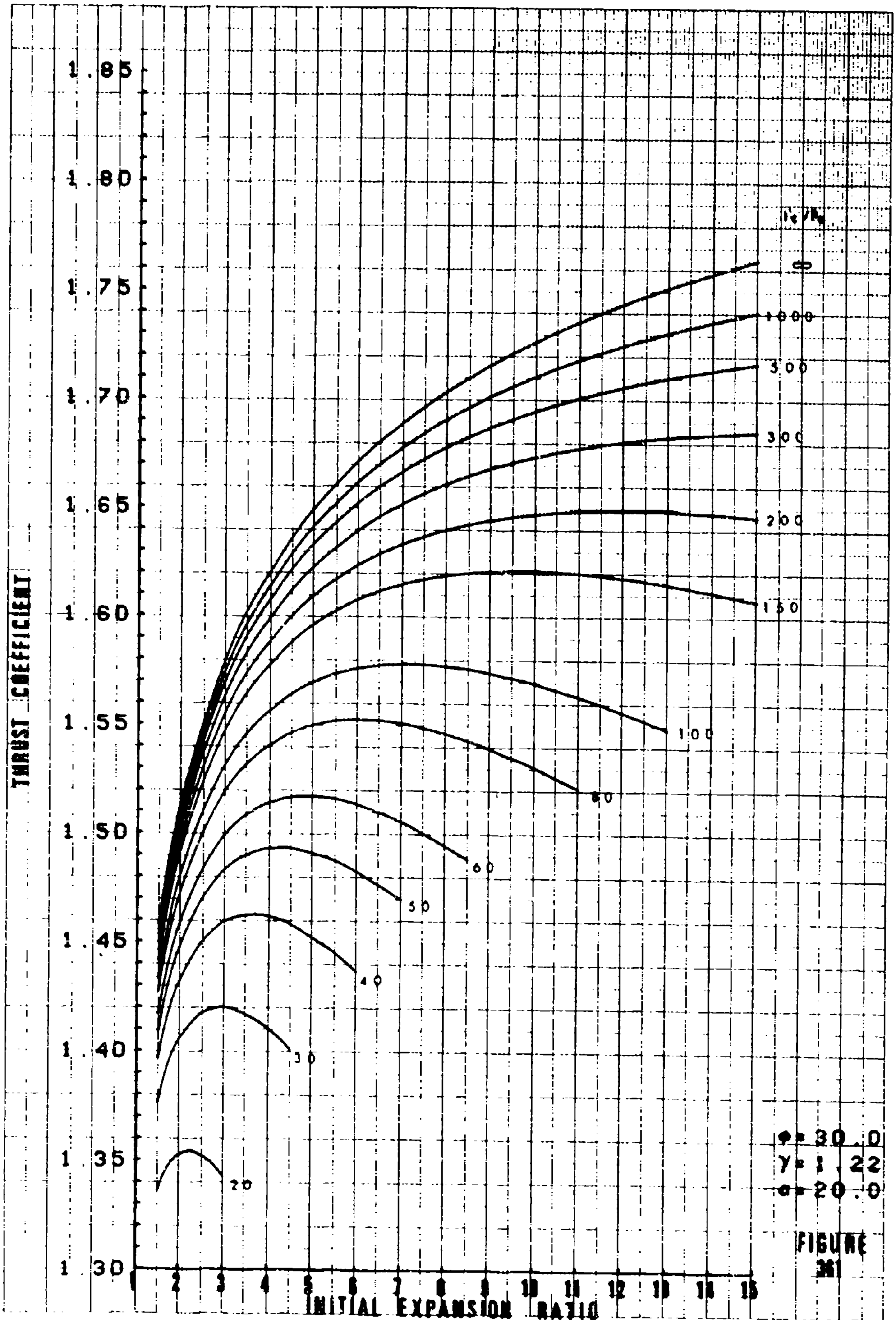

1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
THRUST COEFFICIENT
INITIAL EXPANSION RATIO
P_c/P_a
∞
1000
500
300
200
150
100
80
60
50
40
30
20
Φ= 20.0
γ= 1.22
α= 20.0

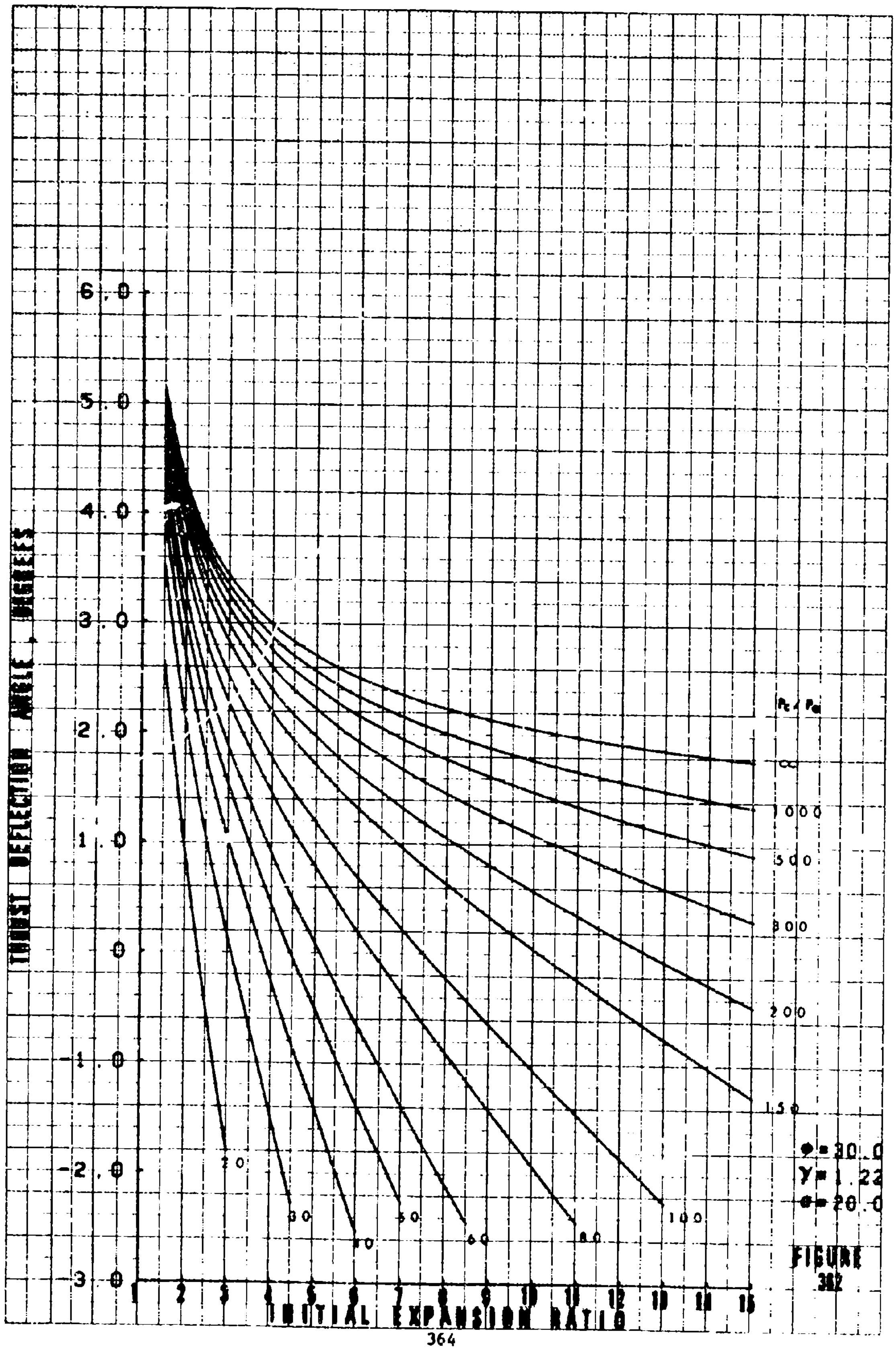
FIGURE 358

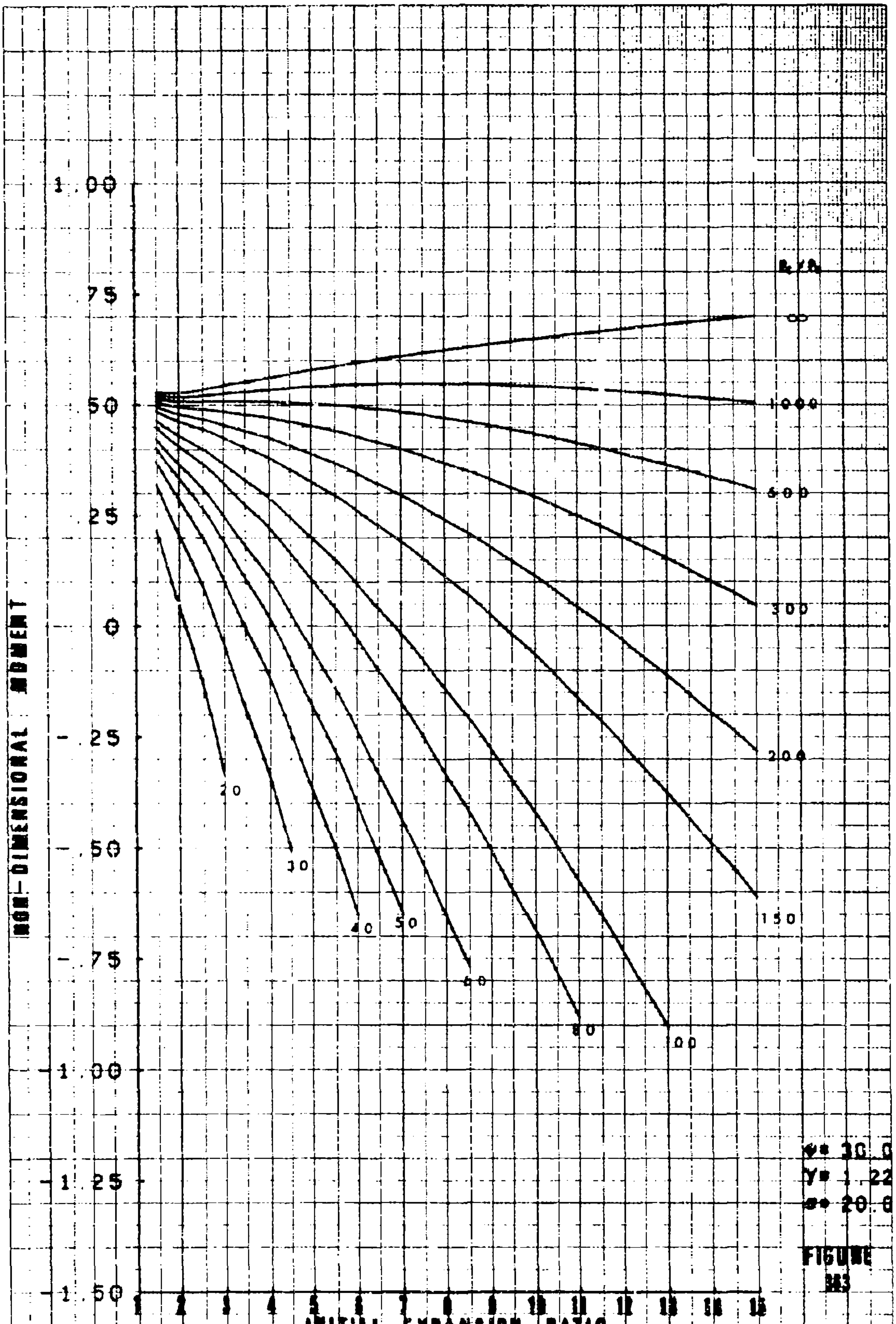

THRUST DEFLECTION ANGLE, DEGREES
4.0
3.0
2.0
1.0
0
-1.0
-2.0
-3.0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
INITIAL EXPANSION RATIO
∞
1000
500
300
200
150
100
80
60
50
40
20
FIGURE


NON-DIMENSIONAL MOMENT
1.00
.75
.50
.25
0
-.25
-.50
-.75
-1.00
-1.25
-1.50
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
INITIAL EXPANSION RATIO
P_c/P_a
∞
1000
500
300
200
150
100
80
60
50
40
30
20
$\phi = 20.0$
$\gamma = 1.22$
$\sigma = 20.0$
FIGURE 360

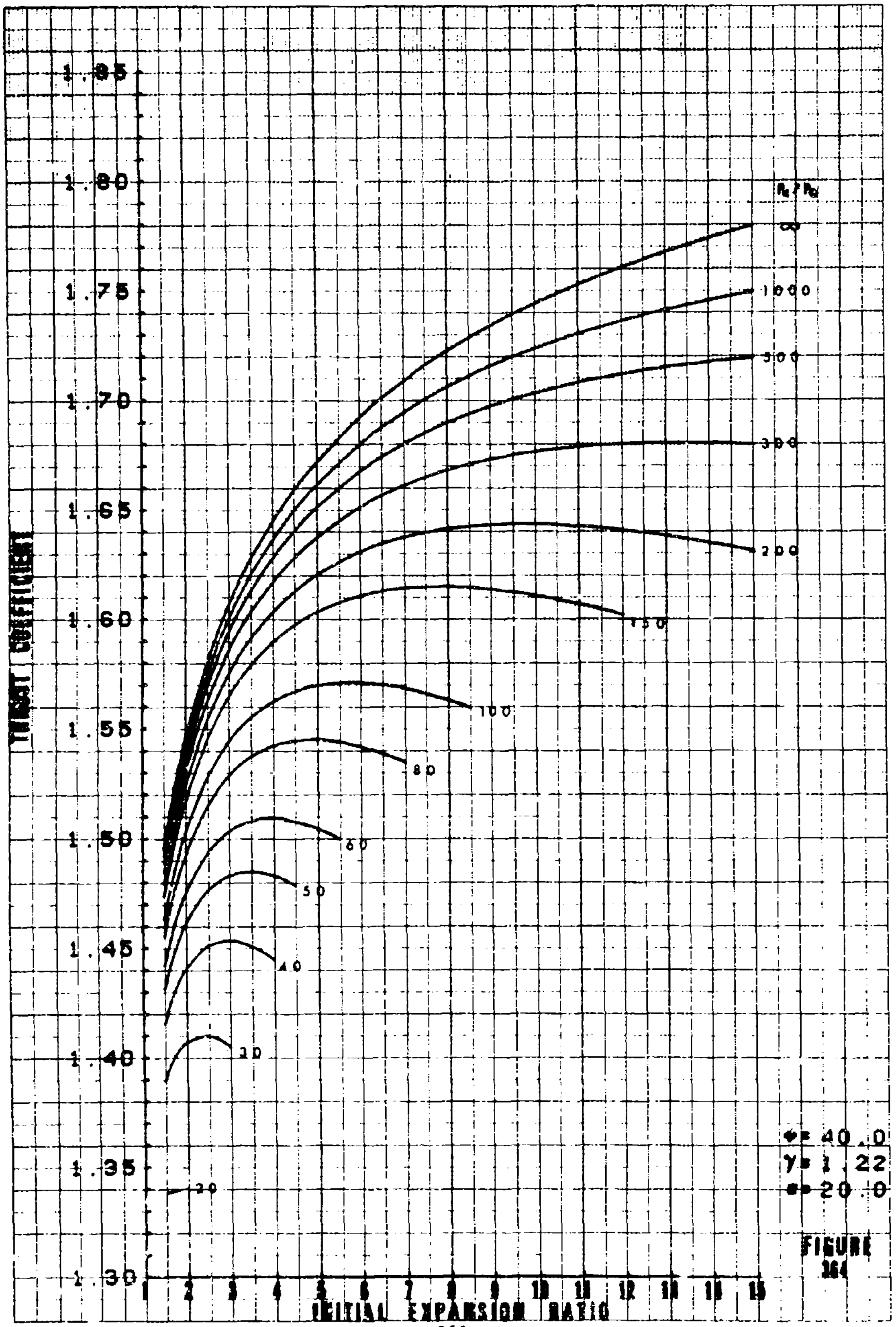


THRUST COEFFICIENT
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
INITIAL EXPANSION RATIO
20
30
40
50
60
80
100
150
200
300
500
1000
∞
φ= 30.0
γ= 1.22
α= 20.0
FIGURE
361


THRUST DEFLECTION ANGLE, DEGREES
INITIAL EXPANSION RATIO
P_c/P_a
∞
1000
500
300
200
150
100
80
60
50
40
30
20
ϕ = 30.0
γ = 1.22
θ = 20.0
FIGURE 362

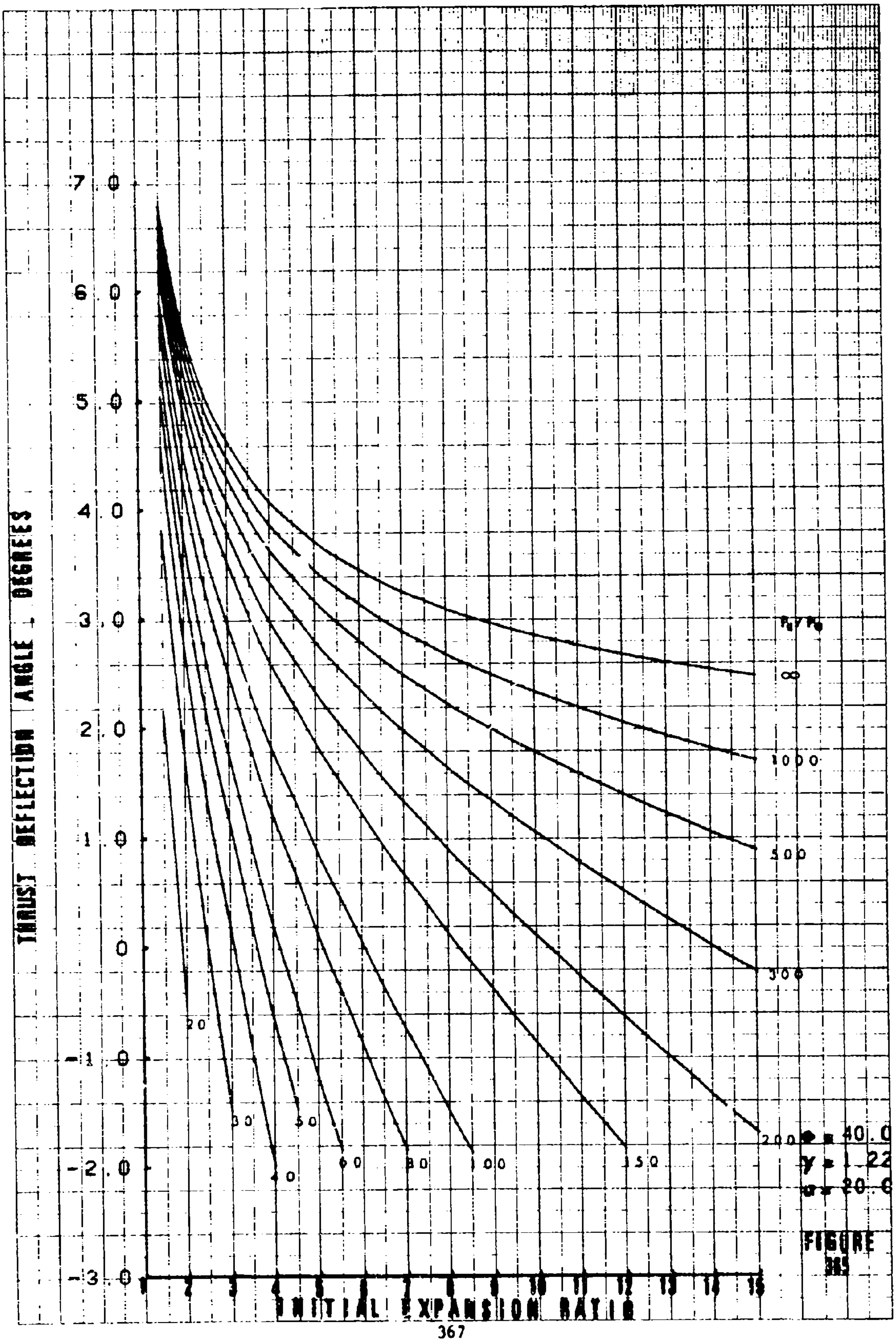


1.00
.75
.50
.25
0
-.25
-.50
-.75
-1.00
-1.25
-1.50
NON-DIMENSIONAL MOMENT
INITIAL EXPANSION RATIO
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
∞
1000
600
300
200
150
100
80
60
50
40
30
20
FIGURE



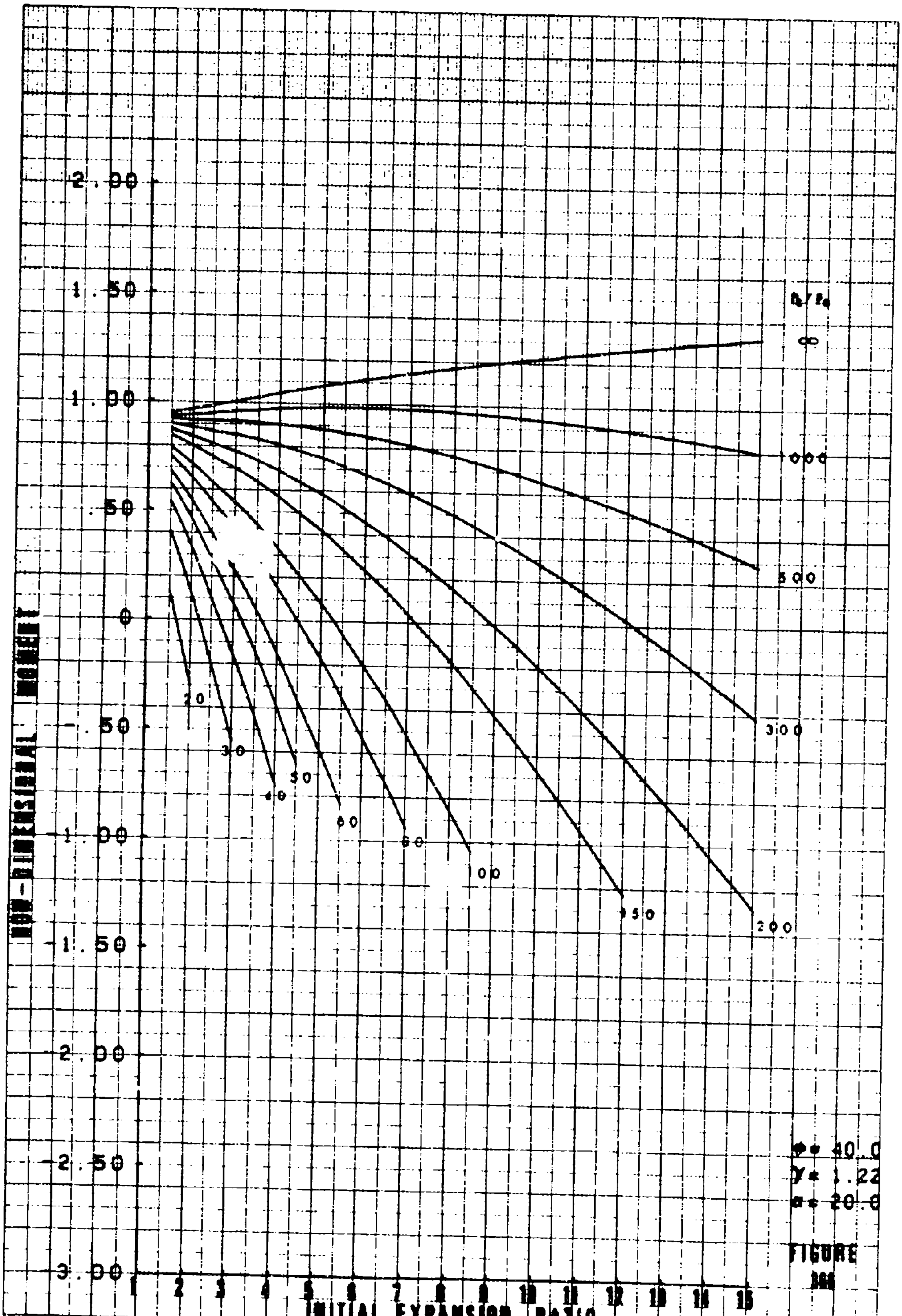
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
THRUST COEFFICIENT
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
INITIAL EXPANSION RATIO
∞
1000
500
300
200
150
100
80
60
50
40
30
20
Φ= 40.0
γ= 1.22
ε= 20.0

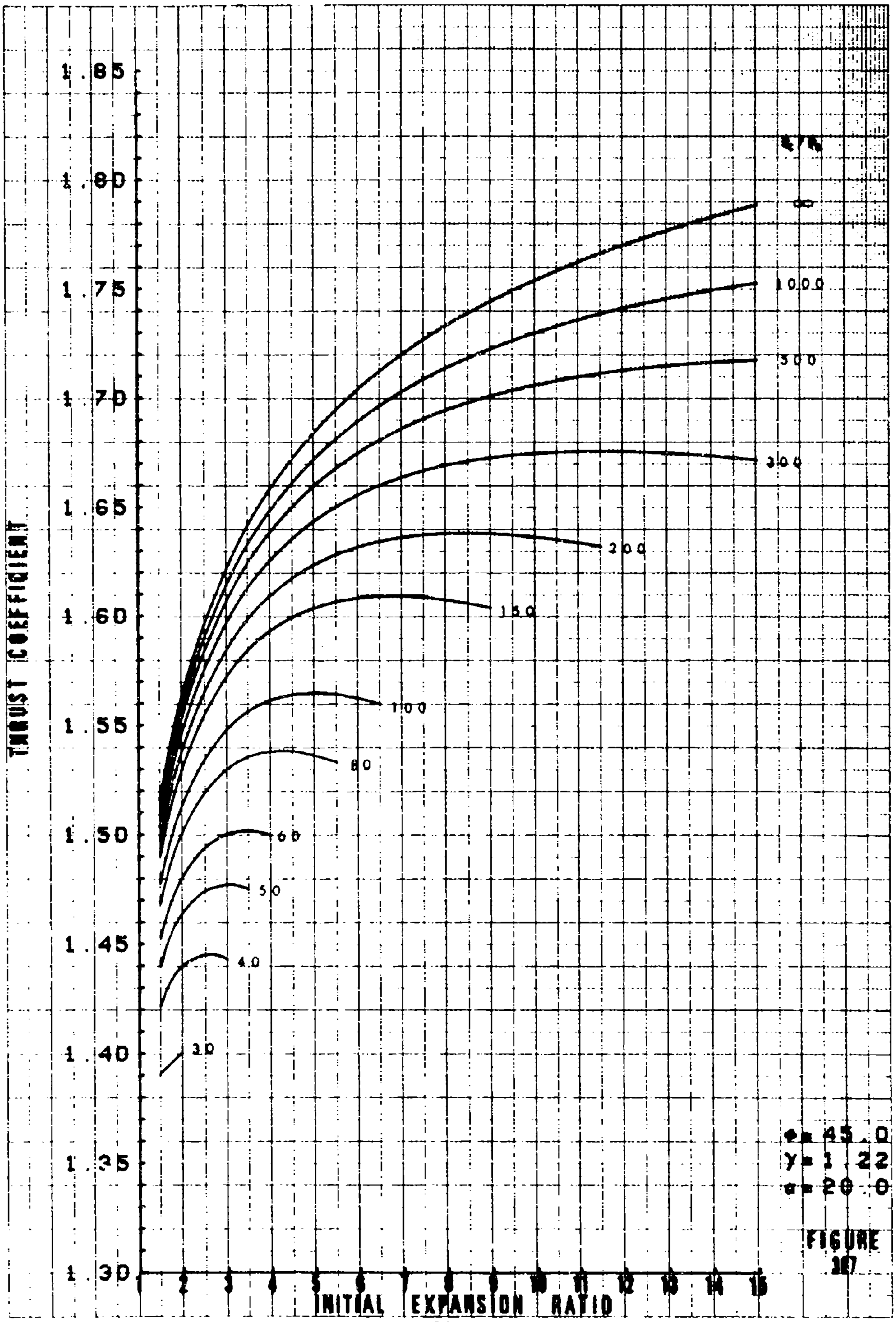
FIGURE 364

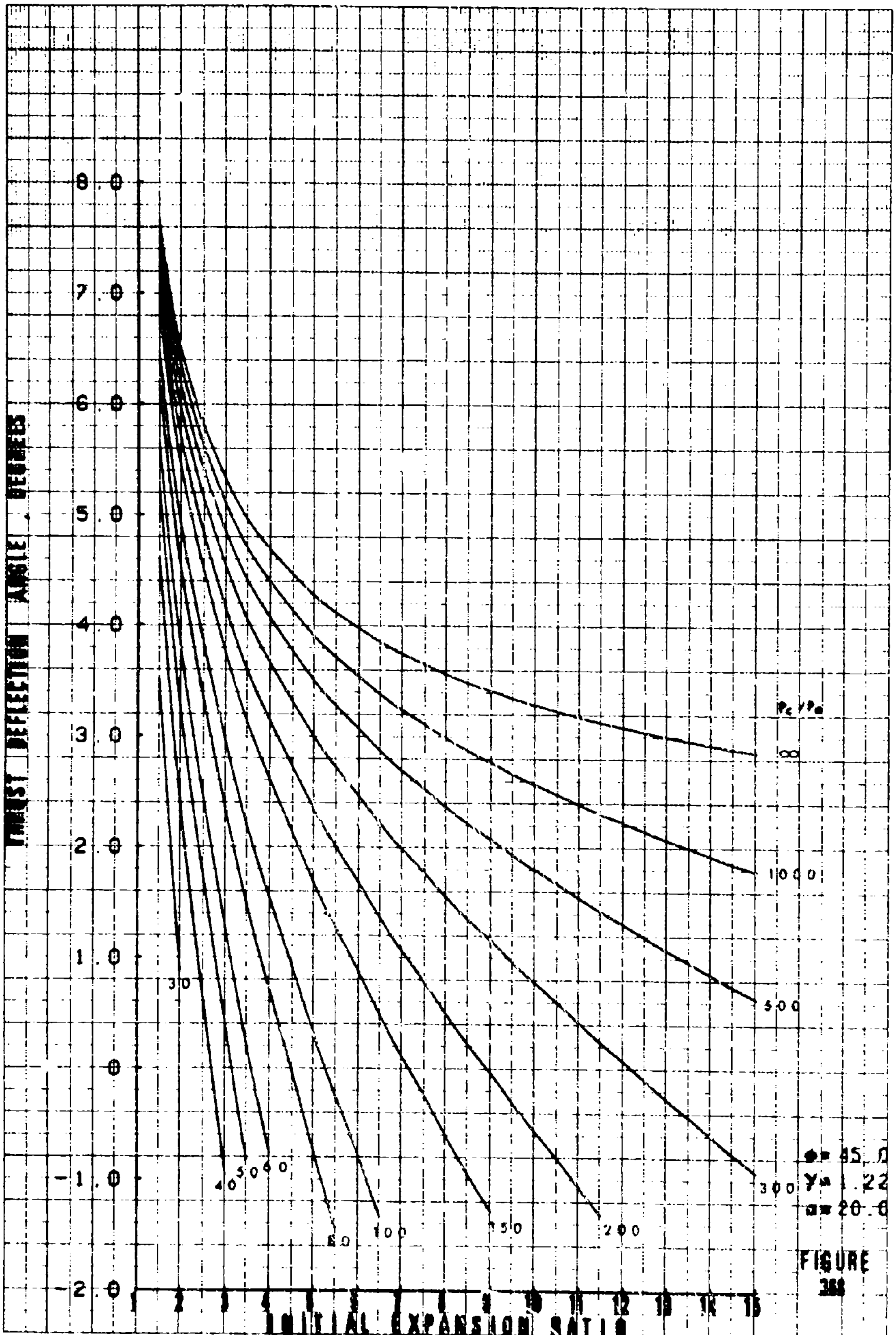


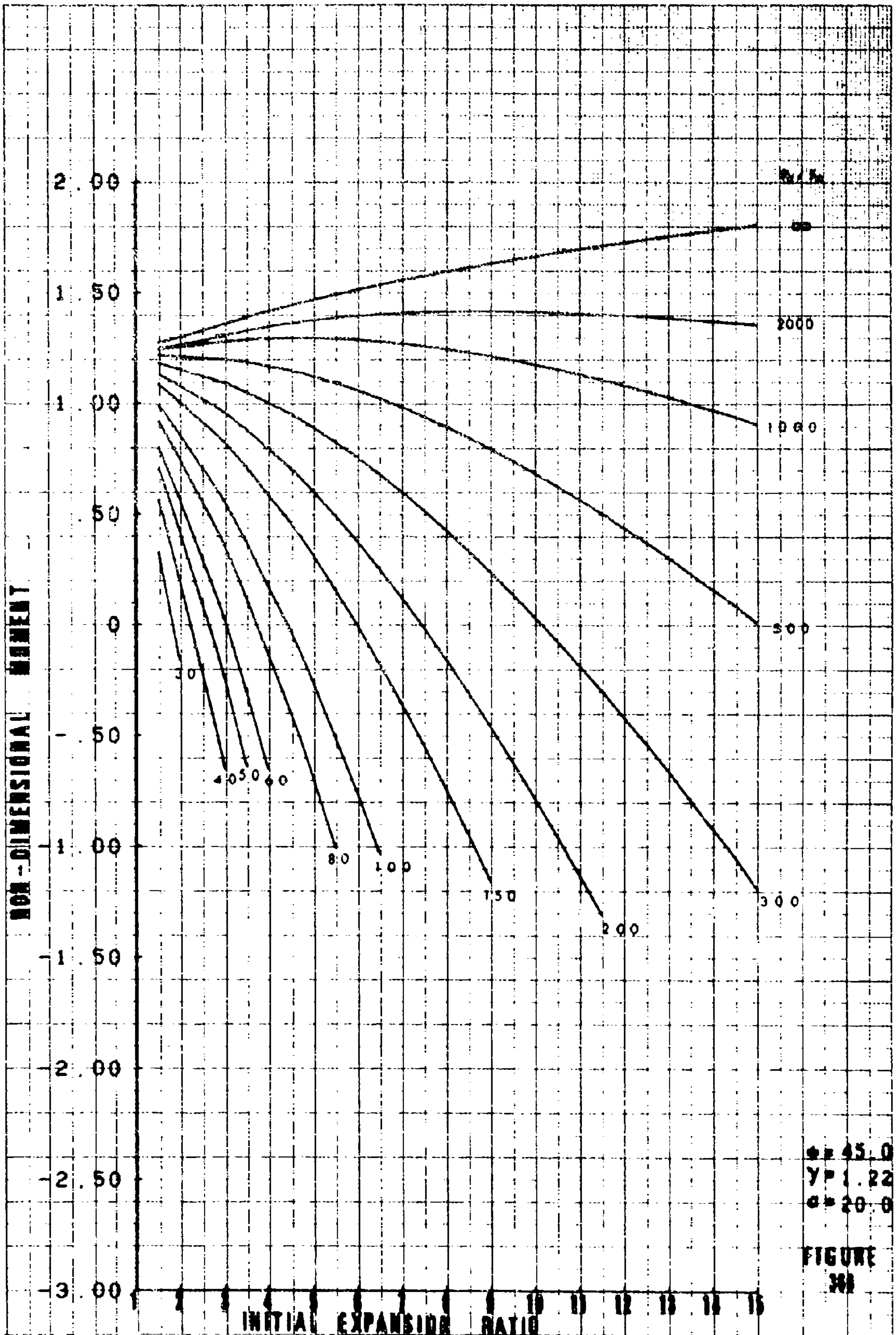
THRUST DEFLECTION ANGLE, DEGREES
INITIAL EXPANSION RATIO
P_c/P_a
∞
1000
500
300
200
150
100
80
60
50
40
30
20
θ = 40.0
γ = 1.22
α = 20.0

FIGURE 365

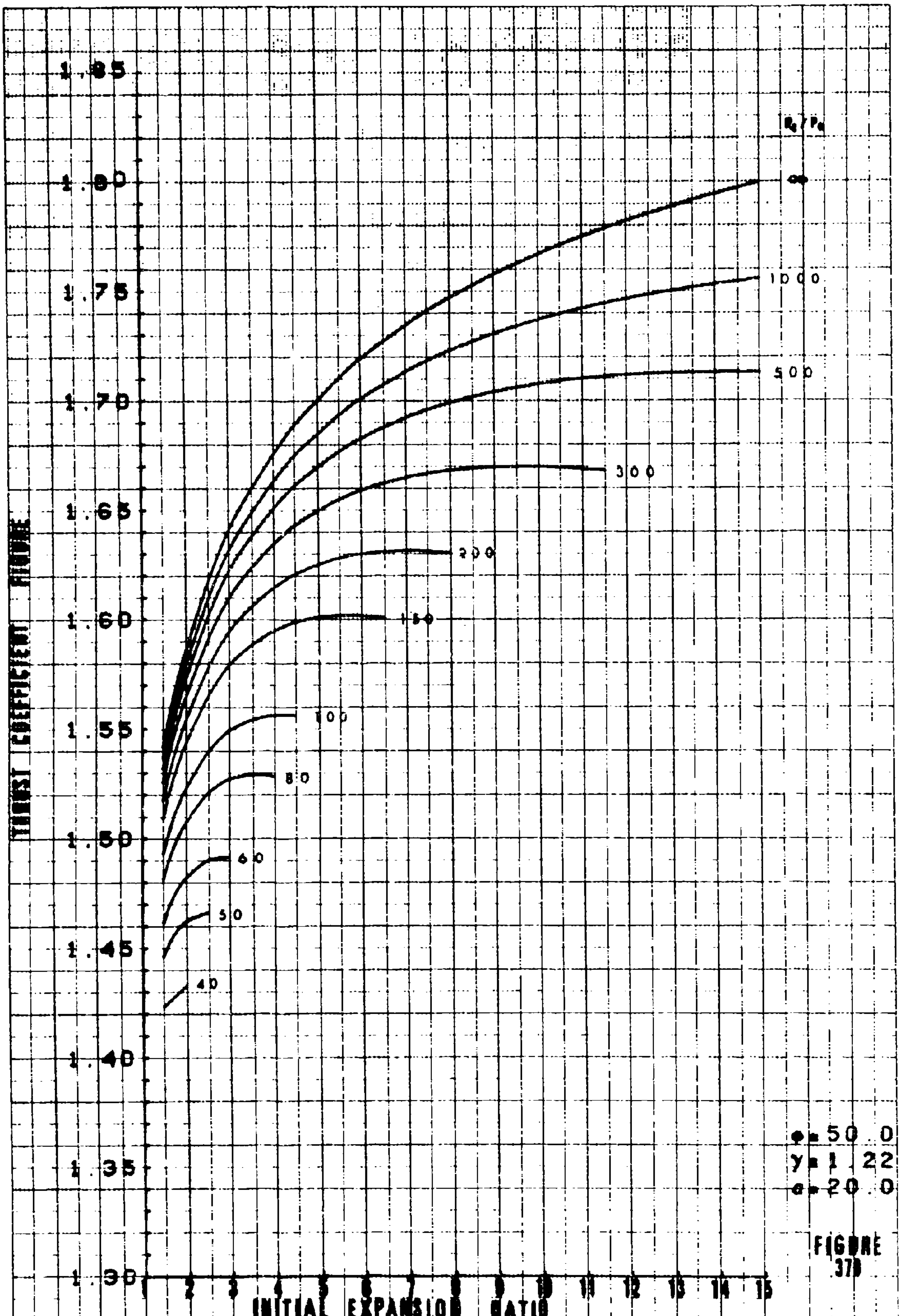

NON-DIMENSIONAL MOMENT
INITIAL EXPANSION RATIO
2.00
1.50
1.00
.50
0
-.50
-1.00
-1.50
-2.00
-2.50
-3.00
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
∞
1000
500
300
200
150
100
80
60
50
40
30
20


THRUST COEFFICIENT
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
INITIAL EXPANSION RATIO
2
3
4
5
6
7
8
9
10
11
12
13
14
15
∞
1000
500
300
200
150
100
80
60
50
40
30
φ = 45.0
γ = 1.22
α = 20.0
FIGURE
107


THRUST DEFLECTION ANGLE, DEGREES
INITIAL EXPANSION RATIO
P_c/P_a
∞
1000
500
300
200
150
100
80
60
50
40
30
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
-1.0
-2.0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15

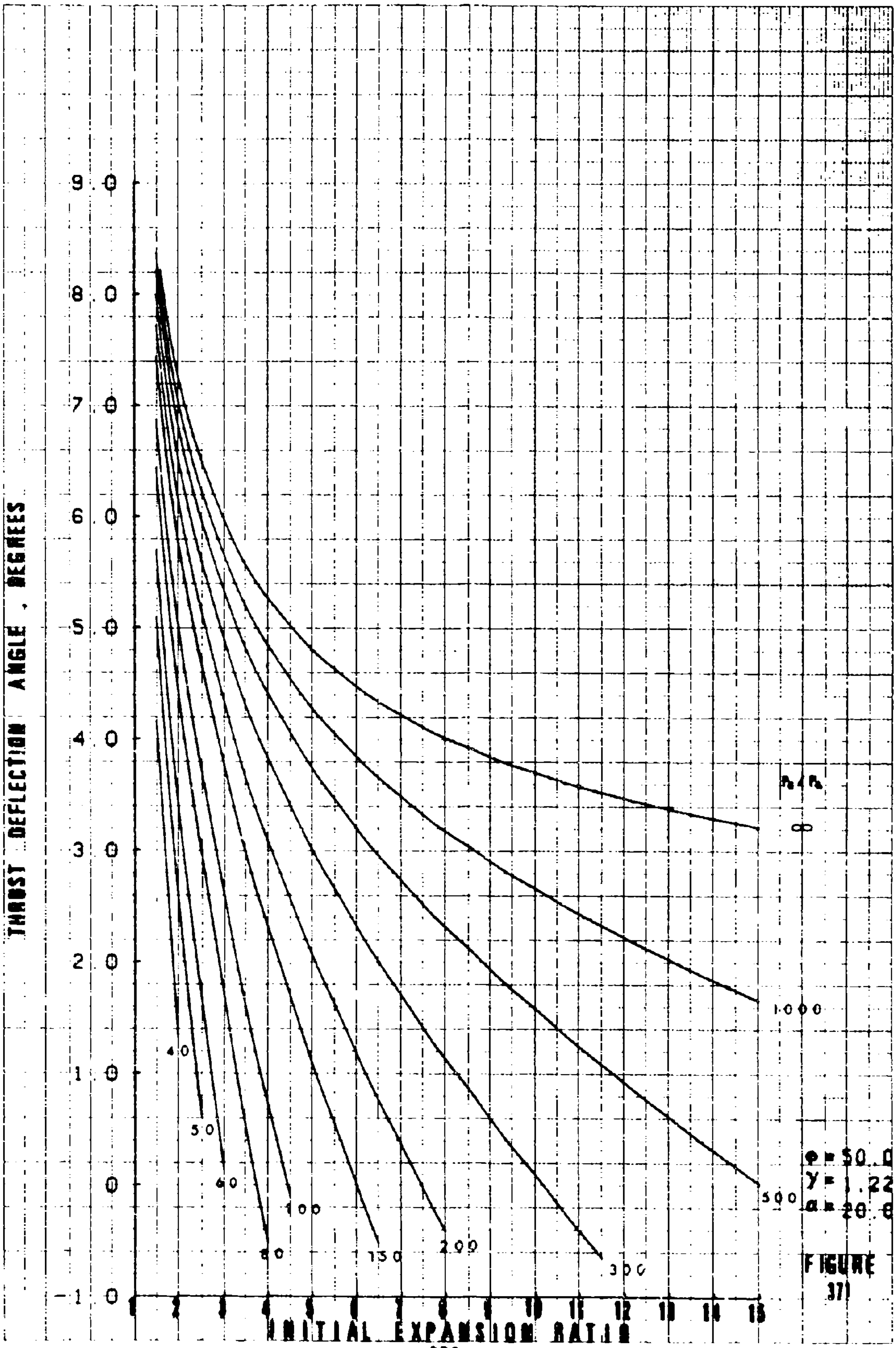


NON-DIMENSIONAL MOMENT
2.00
1.50
1.00
.50
0
-.50
-1.00
-1.50
-2.00
-2.50
-3.00
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
INITIAL EXPANSION RATIO
2000
1000
500
300
200
150
100
80
60
50
40
30

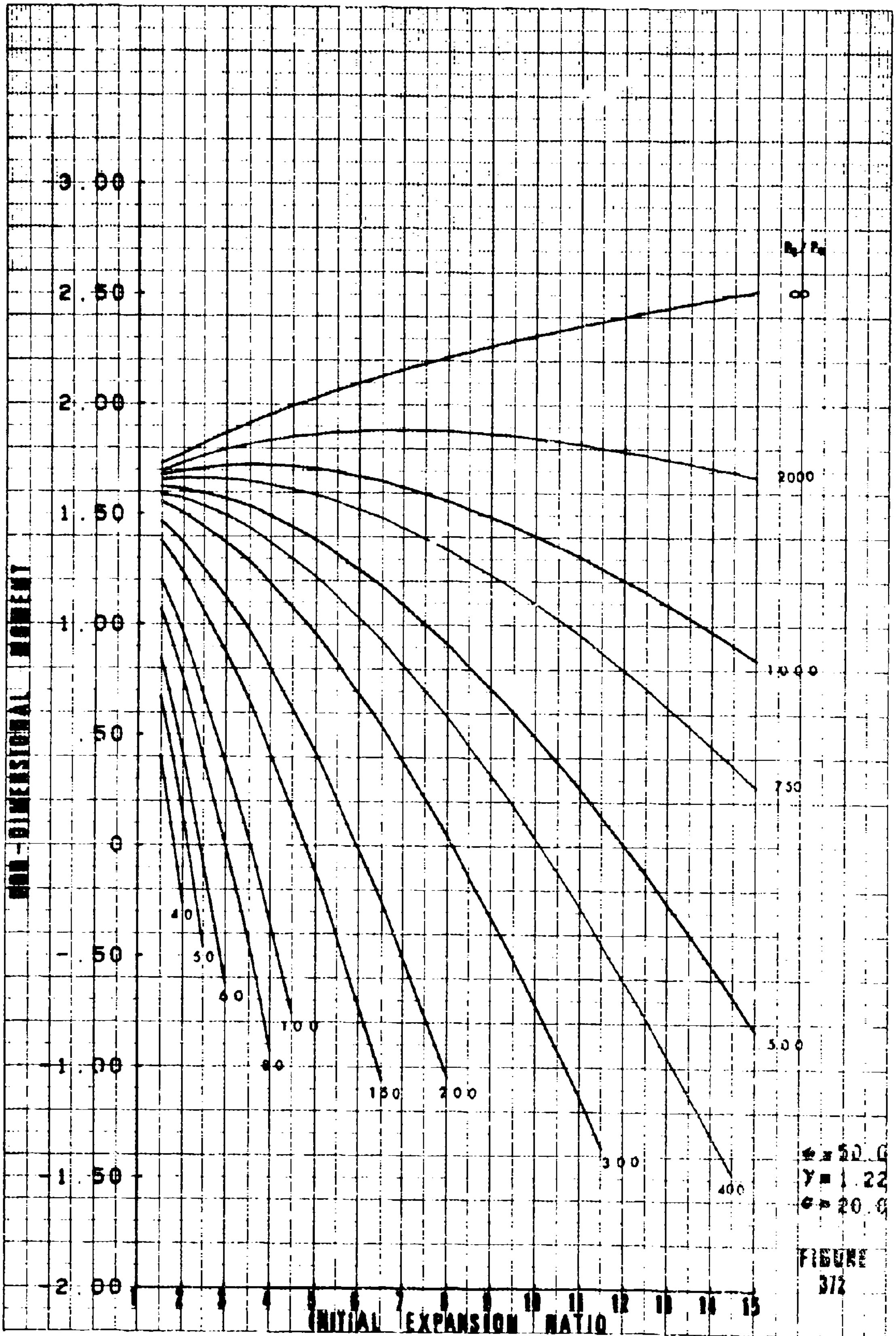


THRUST COEFFICIENT FIGURE
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
INITIAL EXPANSION RATIO
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
∞
1000
500
300
200
150
100
80
60
50
40
φ = 50.0
γ = 1.22
α = 20.0

FIGURE 378

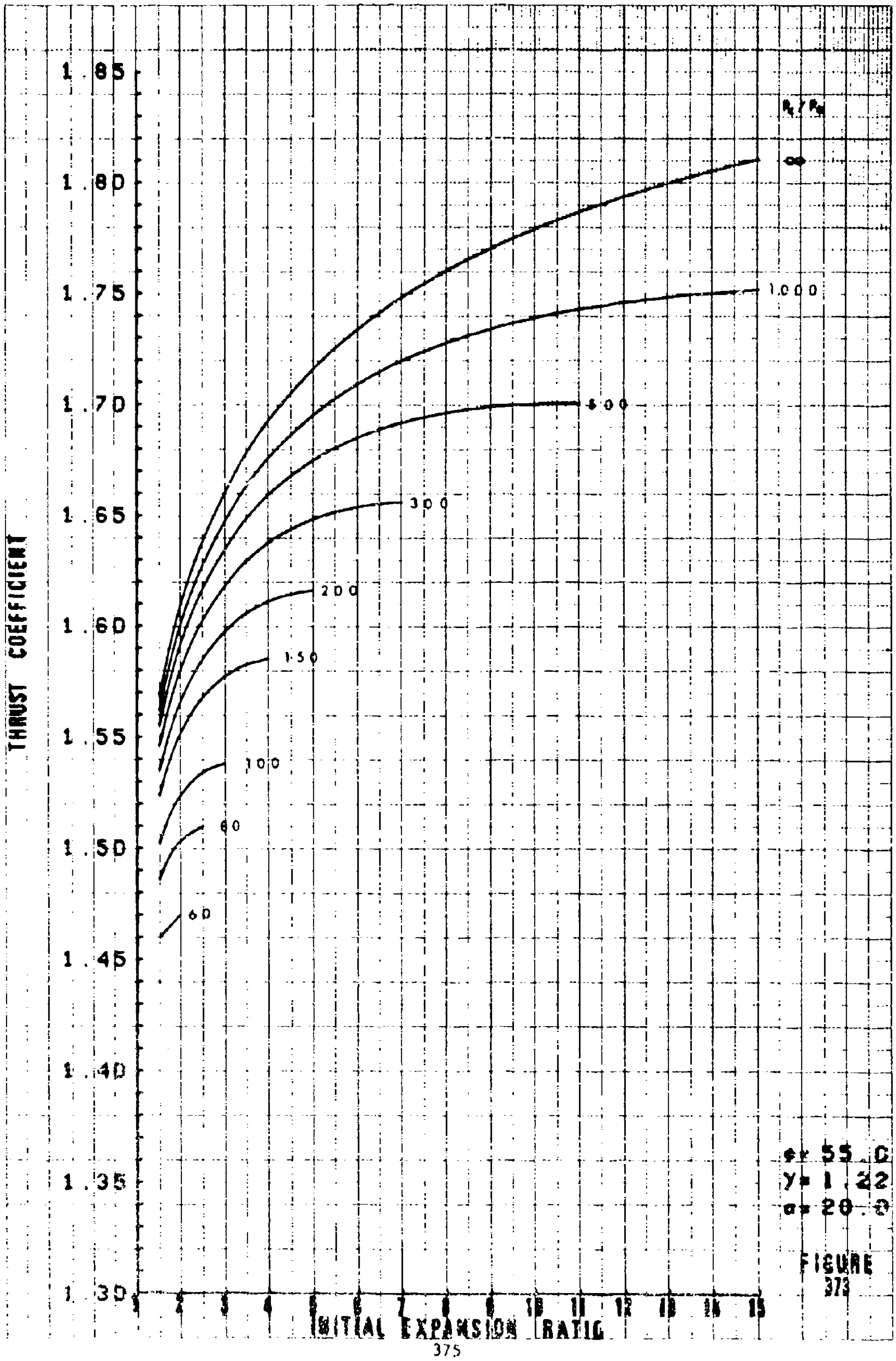


THRUST DEFLECTION ANGLE , DEGREES
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
-1.0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
INITIAL EXPANSION RATIO
40
50
60
80
100
150
200
300
500
1000
∞



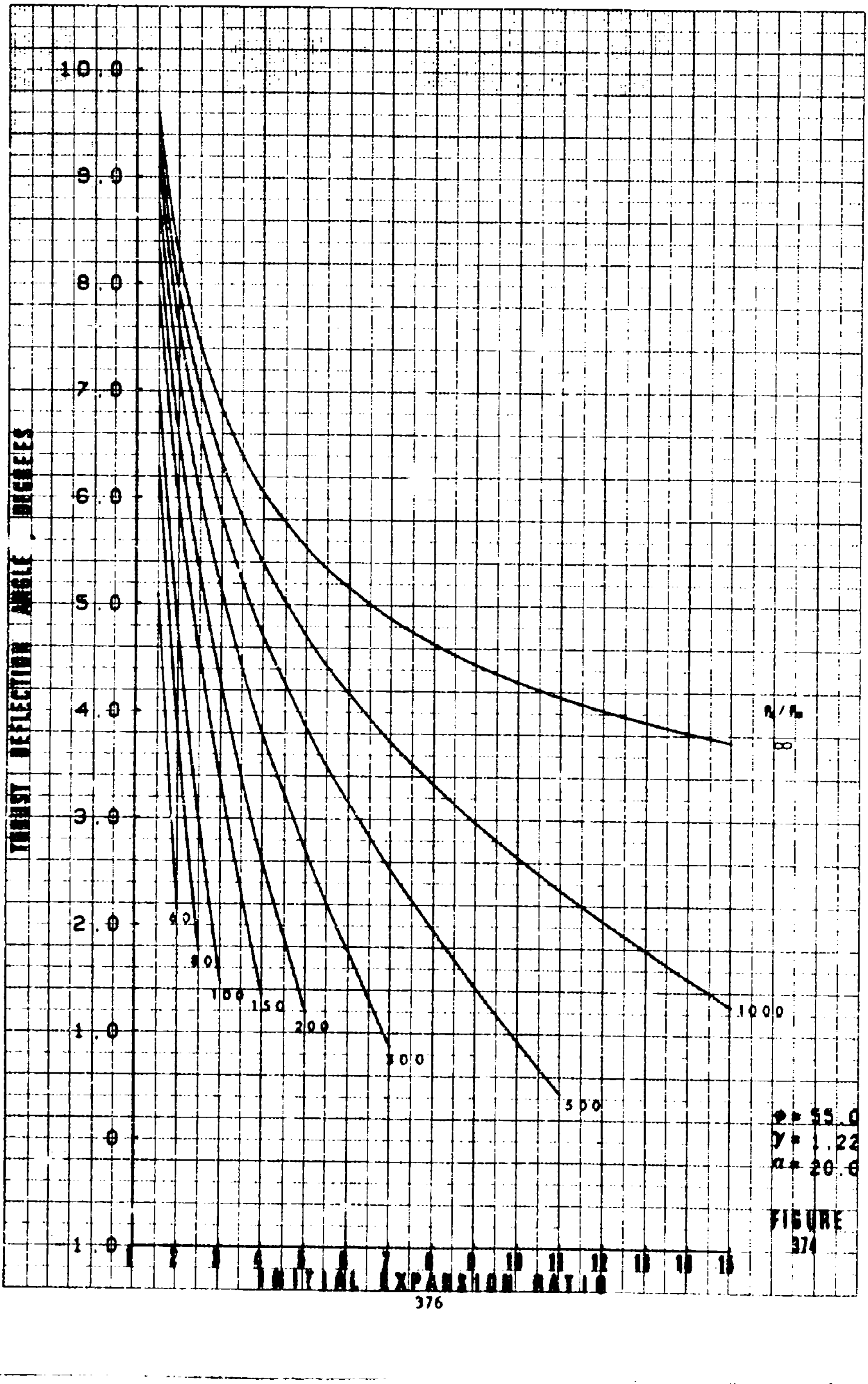
NON-DIMENSIONAL MOMENT
INITIAL EXPANSION RATIO
3.00
2.50
2.00
1.50
1.00
.50
0
-.50
-1.00
-1.50
-2.00
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
∞
2000
1000
750
500
400
300
200
150
100
80
60
50
40

FIGURE 372

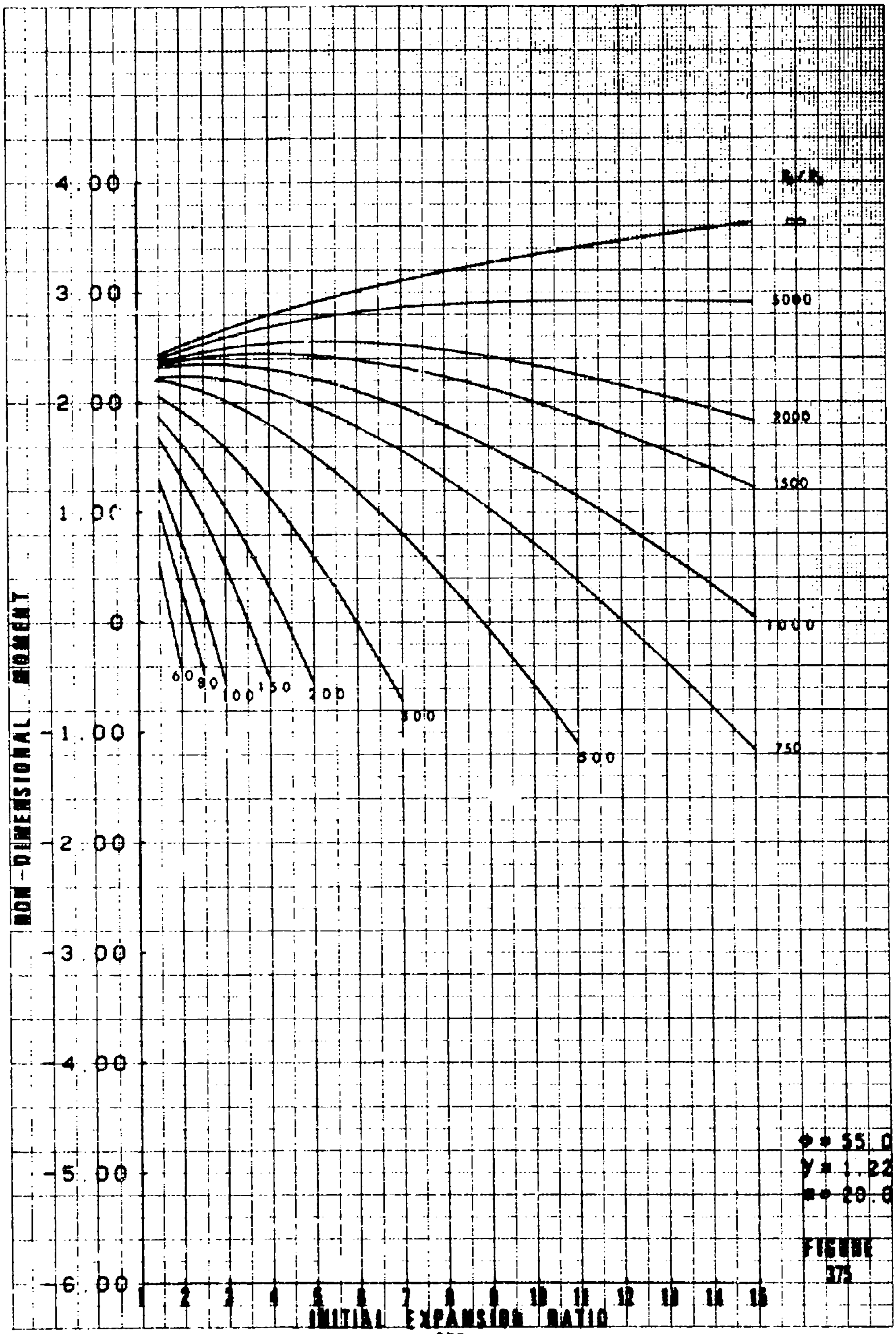


THRUST COEFFICIENT
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
INITIAL EXPANSION RATIO
1000
500
300
200
150
100
80
60

FIGURE 373

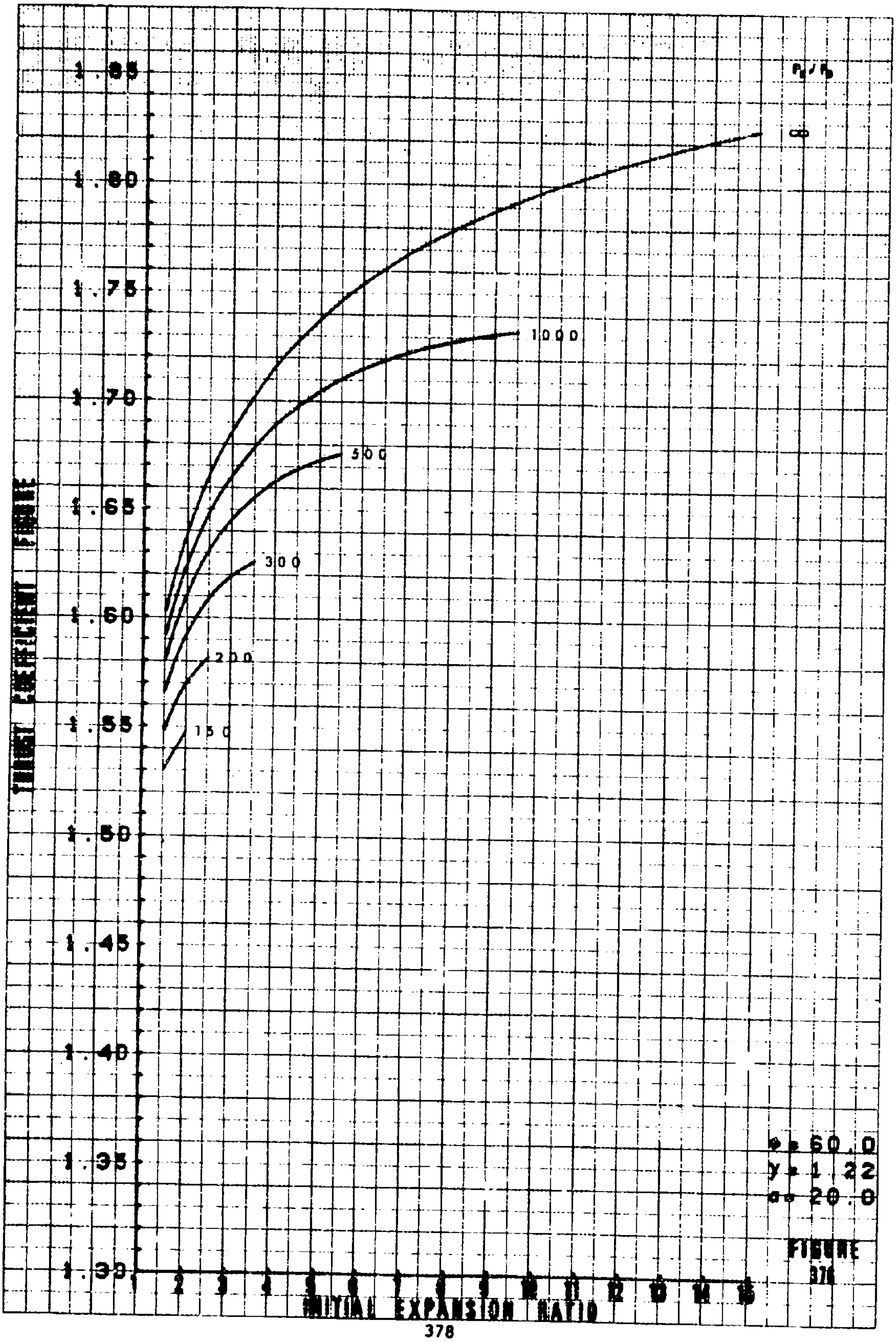


THRUST DEFLECTION ANGLE , DEGREES
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
1.0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
INITIAL EXPANSION RATIO
60
80
100
150
200
300
500
1000
∞
Φ = 55.0
γ = 1.22
α = 20.0
FIGURE 374



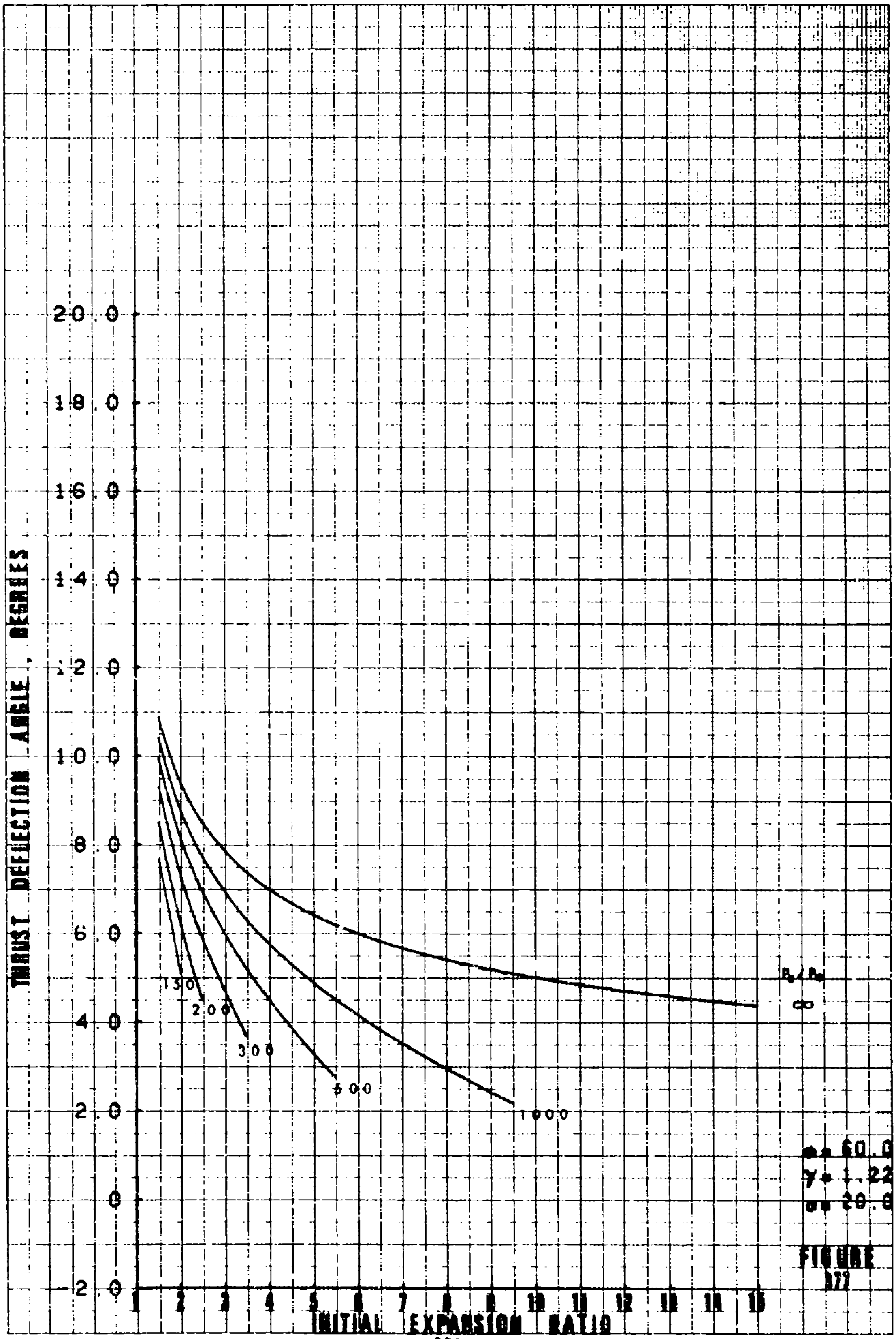
NON-DIMENSIONAL MOMENT
INITIAL EXPANSION RATIO
4.00
3.00
2.00
1.00
0
-1.00
-2.00
-3.00
-4.00
-5.00
-6.00
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
5000
2000
1500
1000
750
60
80
100
150
200
300
500

FIGURE 375



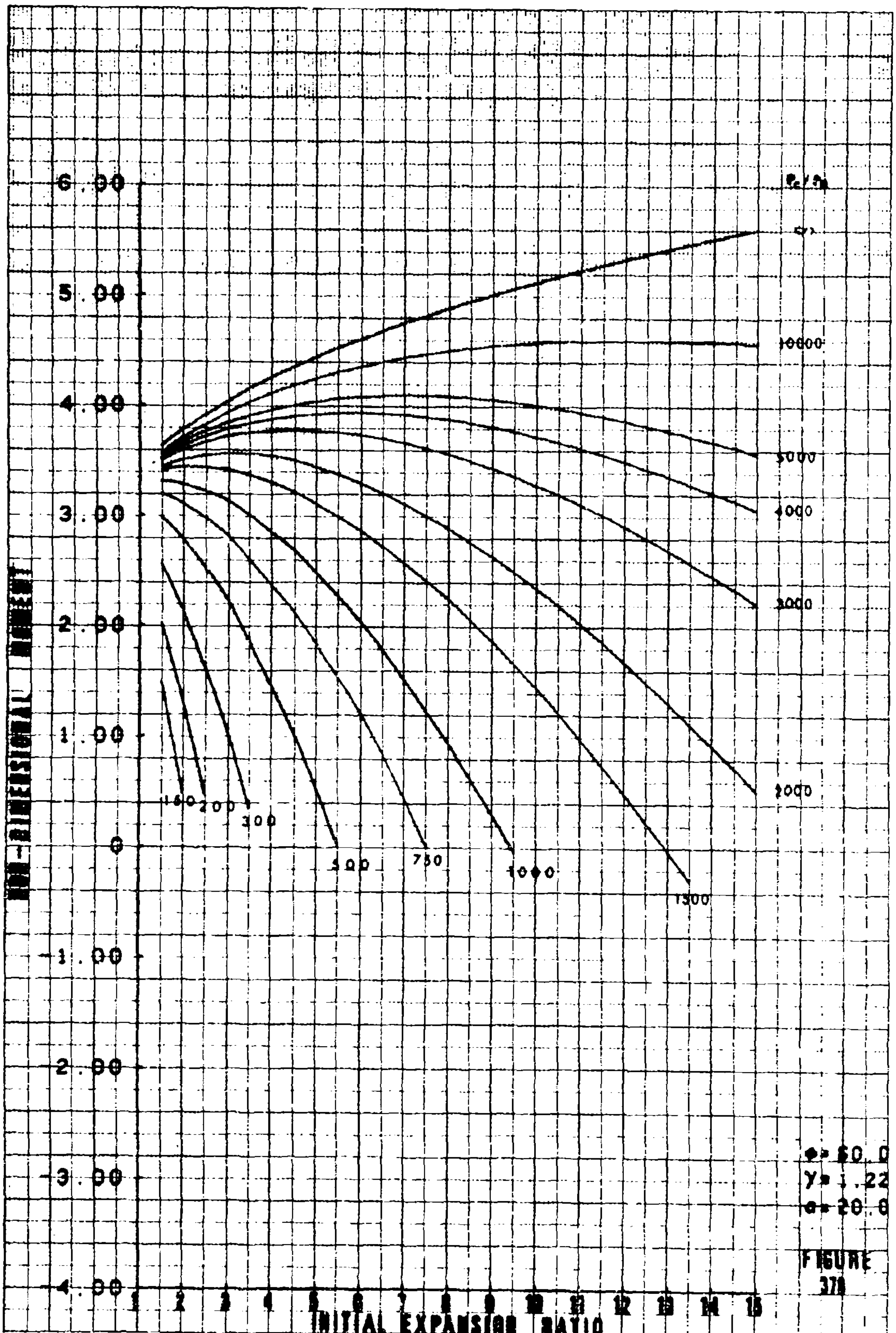
THRUST COEFFICIENT FIGURE
INITIAL EXPANSION RATIO
P_c/P_a
∞
1000
500
300
200
150
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
2
3
4
5
6
7
8
9
10
11
12
13
14
15
φ = 60.0
γ = 1.22
α = 20.0

FIGURE 378



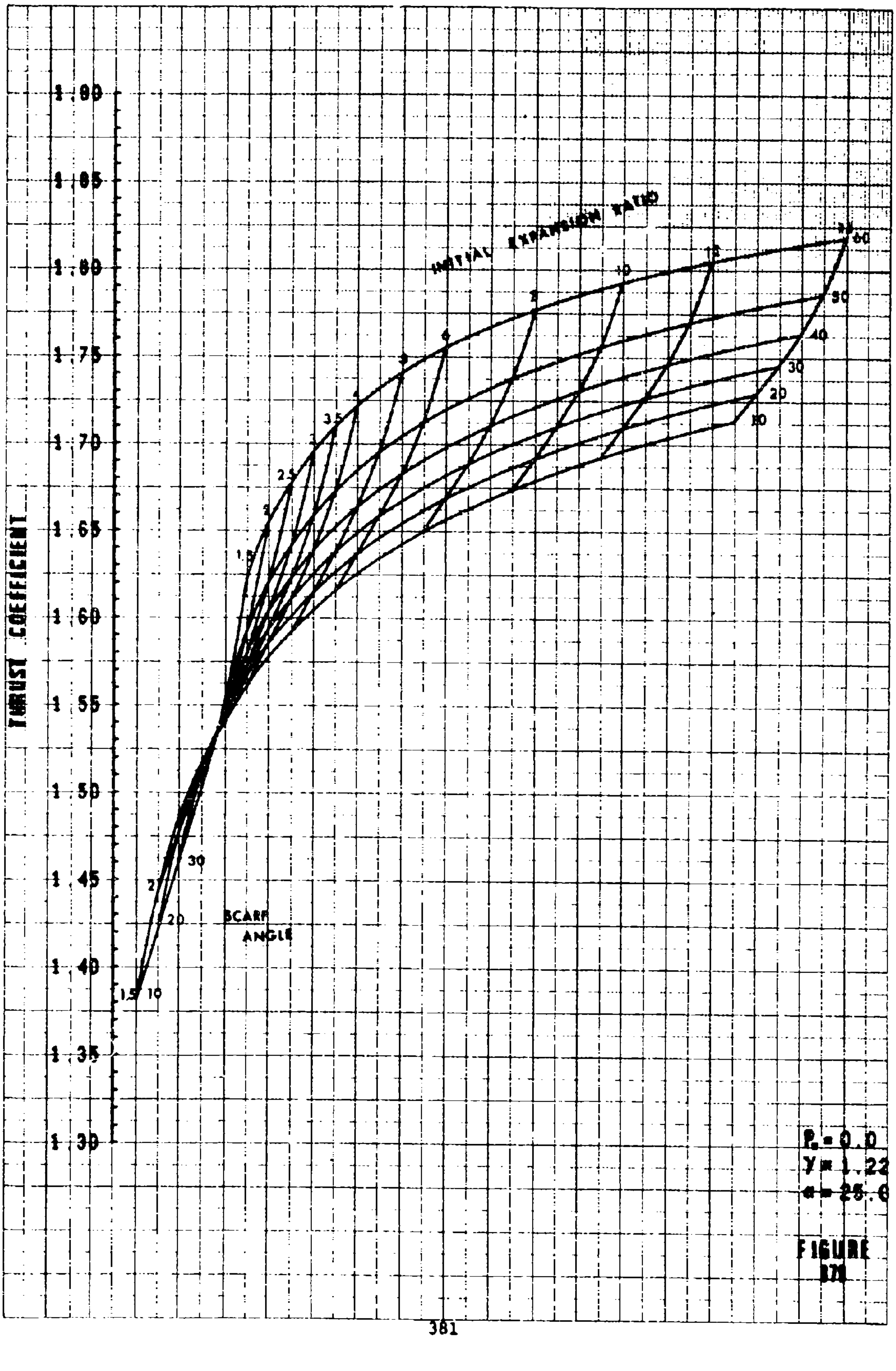
THRUST DEFLECTION ANGLE, DEGREES
20.0
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0
-2.0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
INITIAL EXPANSION RATIO
150
200
300
500
1000
∞
γ = 1.22

FIGURE 377



NON-DIMENSIONAL MOMENT
INITIAL EXPANSION RATIO
6.00
5.00
4.00
3.00
2.00
1.00
0
-1.00
-2.00
-3.00
-4.00
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
P_c/P_a
∞
10000
5000
4000
3000
2000
1500
1000
750
500
300
200
150
ϕ= 50.0
γ= 1.22
α= 20.0

FIGURE 378



THRUST COEFFICIENT
1.80
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
INITIAL EXPANSION RATIO
SCARF ANGLE
FIGURE

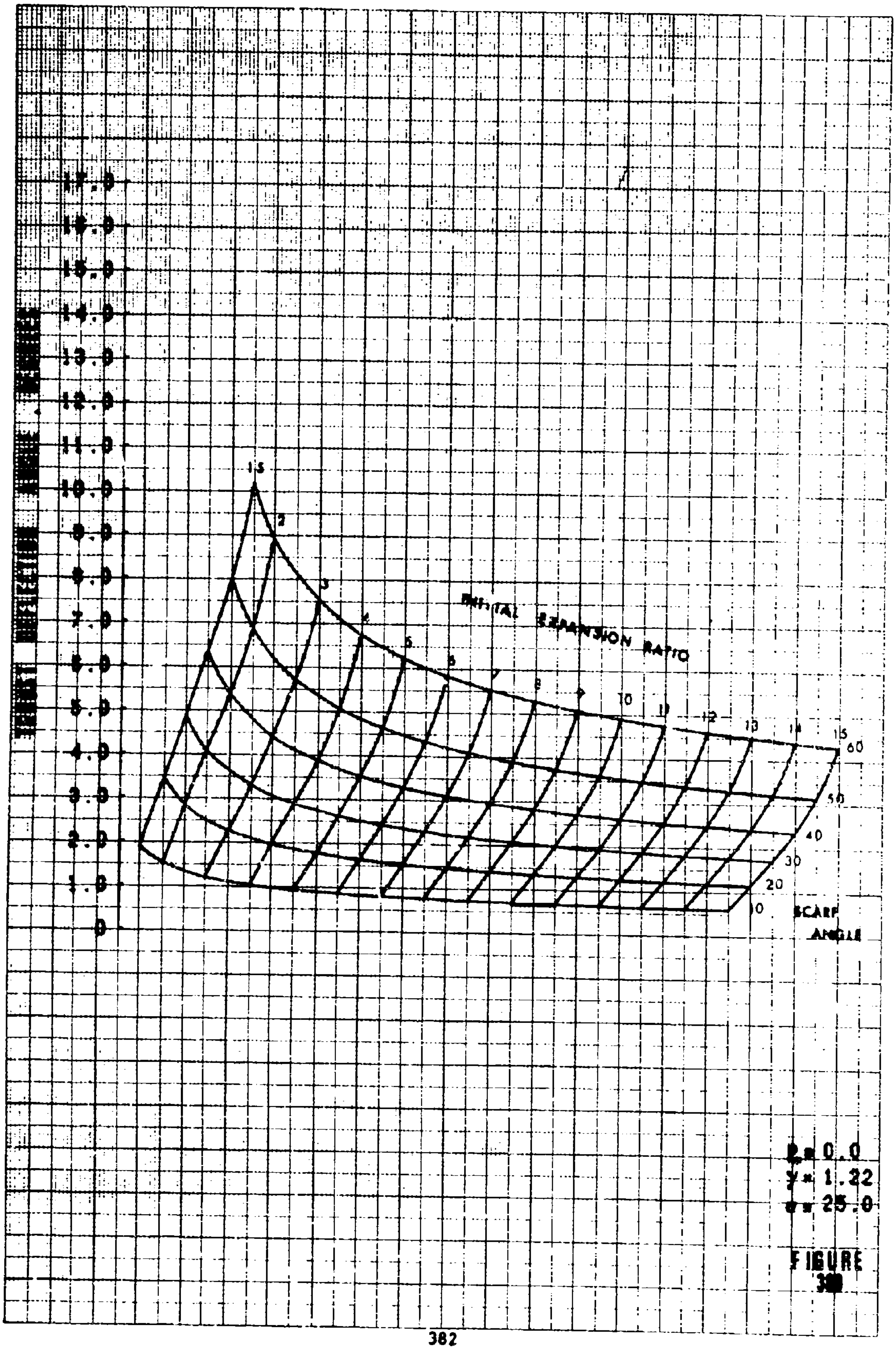
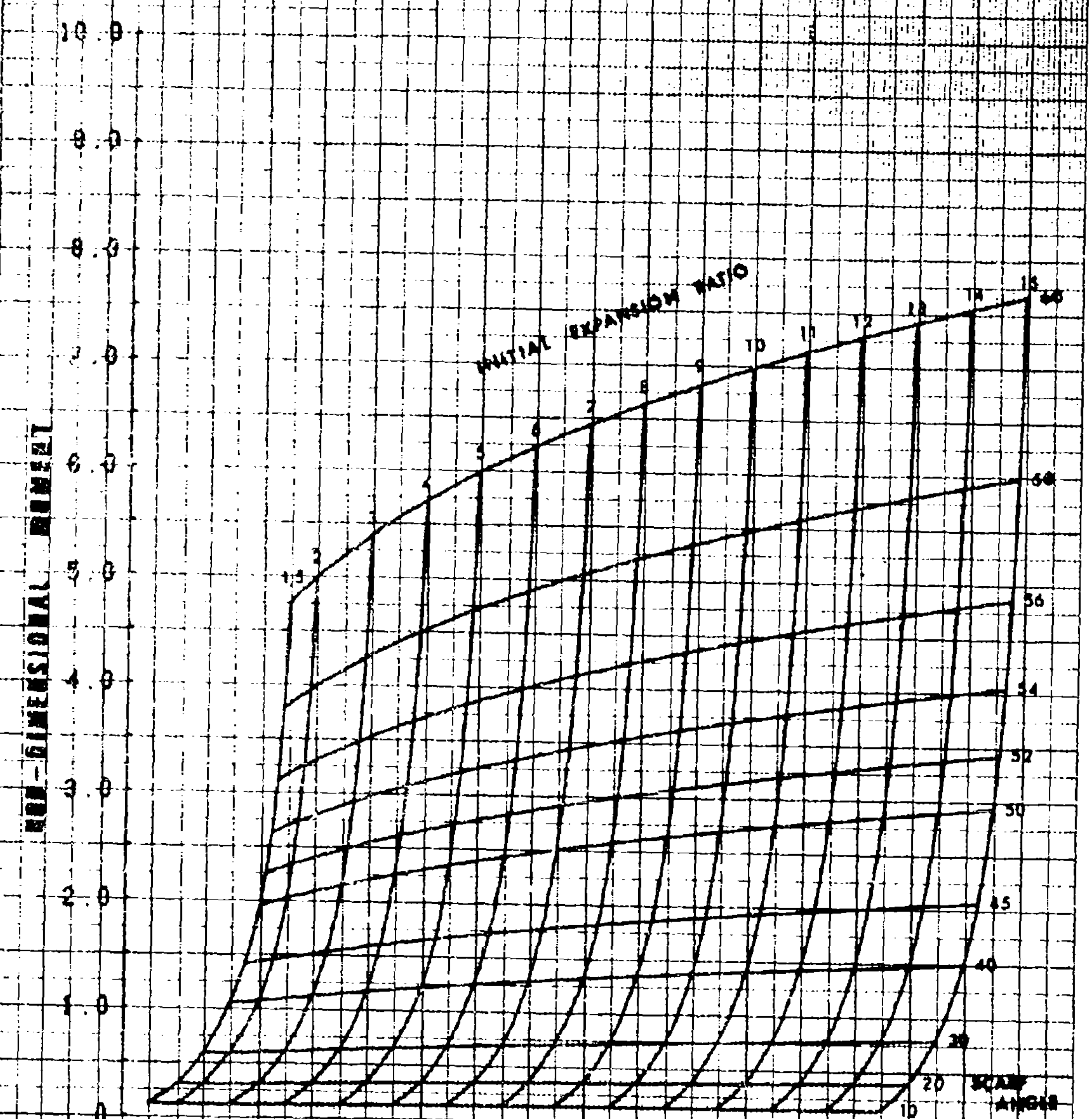
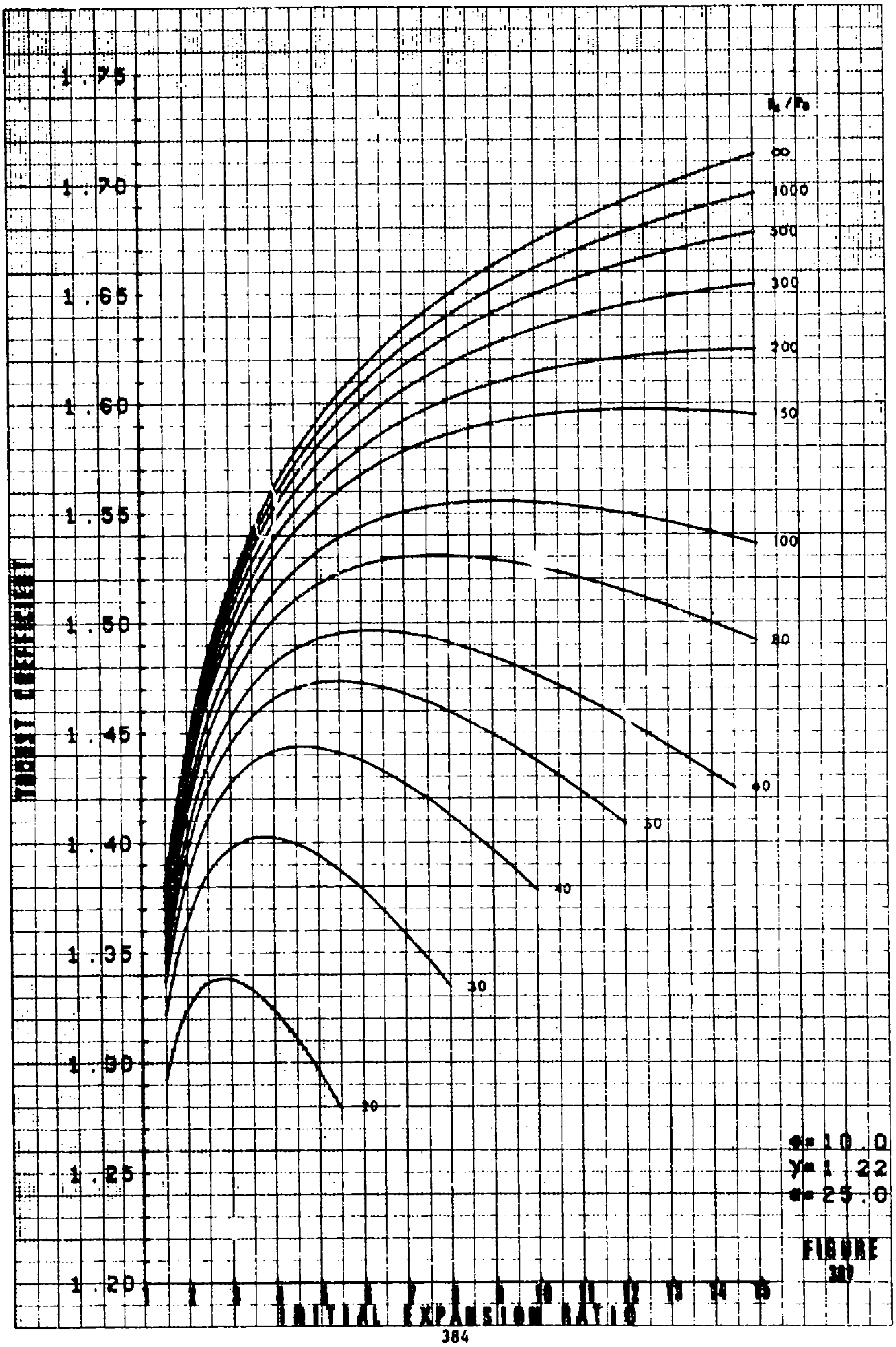

17.0
16.0
15.0
14.0
13.0
12.0
11.0
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
INITIAL EXPANSION RATIO
1.5
2
3
4
5
6
7
8
9
10
11
12
13
14
15
60
50
40
30
20
10
SCARF ANGLE
γ = 1.22
= 25.0

FIGURE 3[illegible]

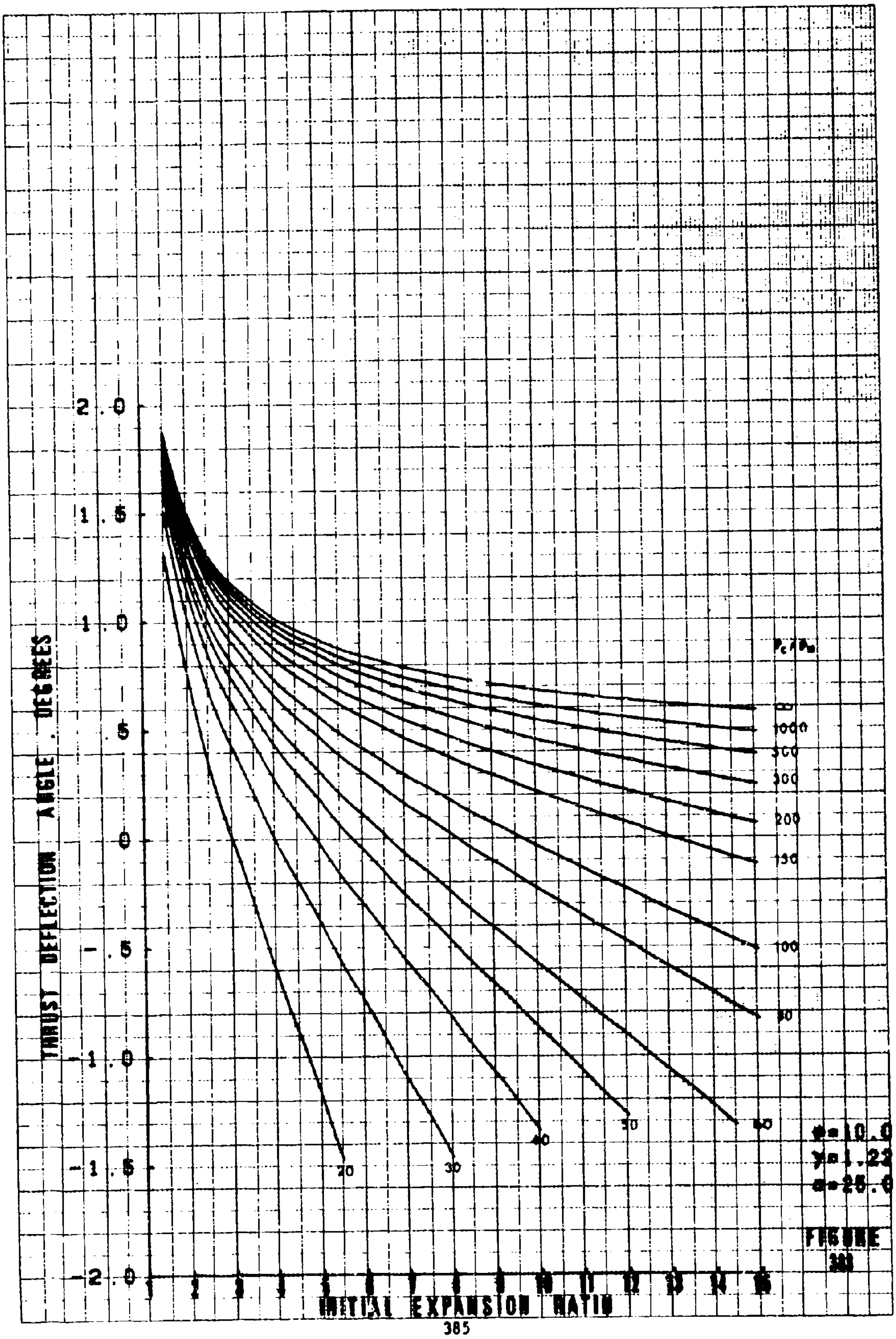


NON-DIMENSIONAL MOMENT
INITIAL EXPANSION RATIO
SCARF ANGLE
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
1.5
2
3
4
5
6
7
8
9
10
11
12
13
14
15
60
58
56
54
52
50
45
40
30
20
10

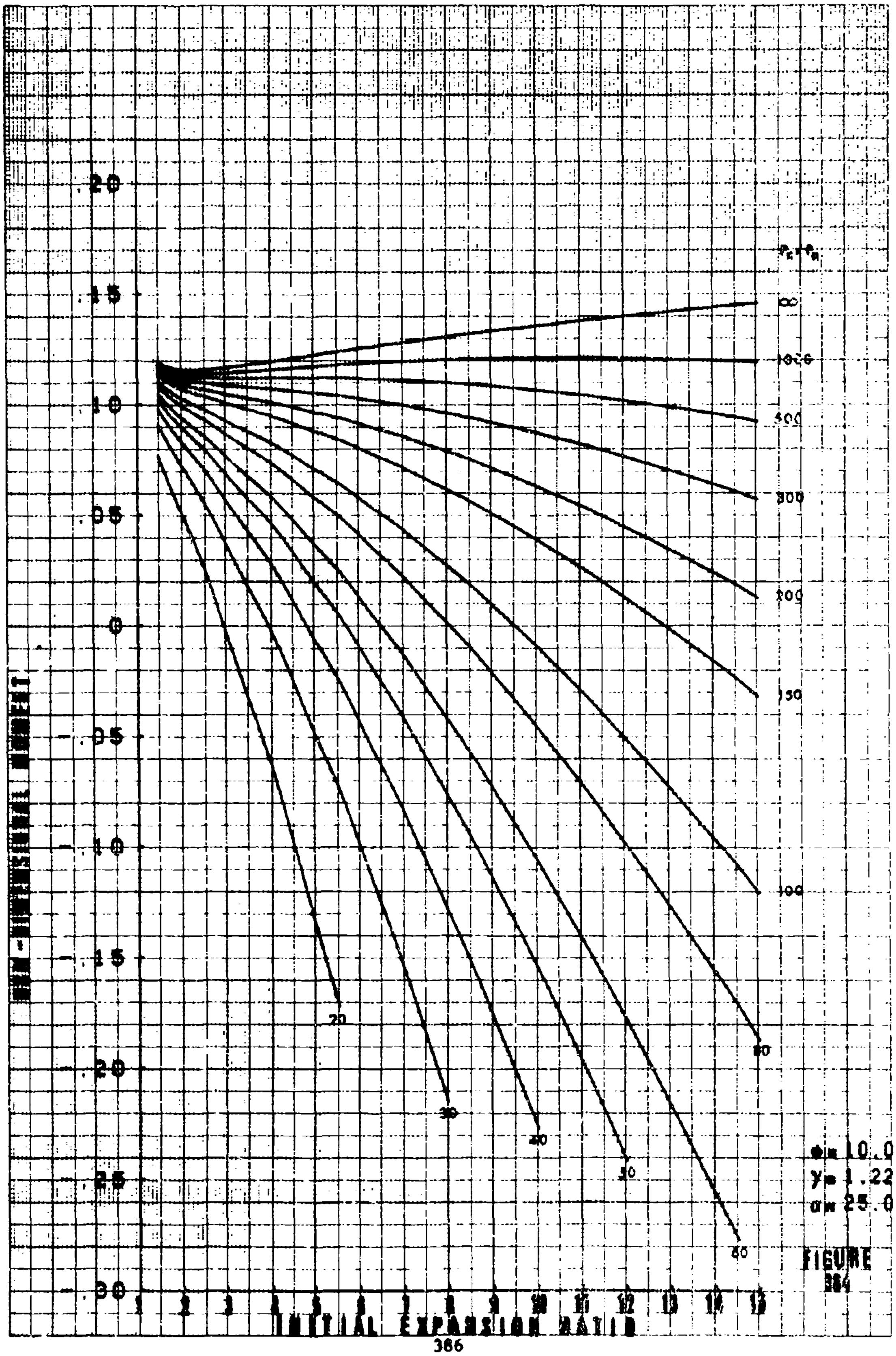
FIGURE



1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
1.25
1.20
THRUST COEFFICIENT
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
INITIAL EXPANSION RATIO
∞
1000
500
300
200
150
100
80
60
50
40
30
20
10.0
1.22
25.0
FIGURE

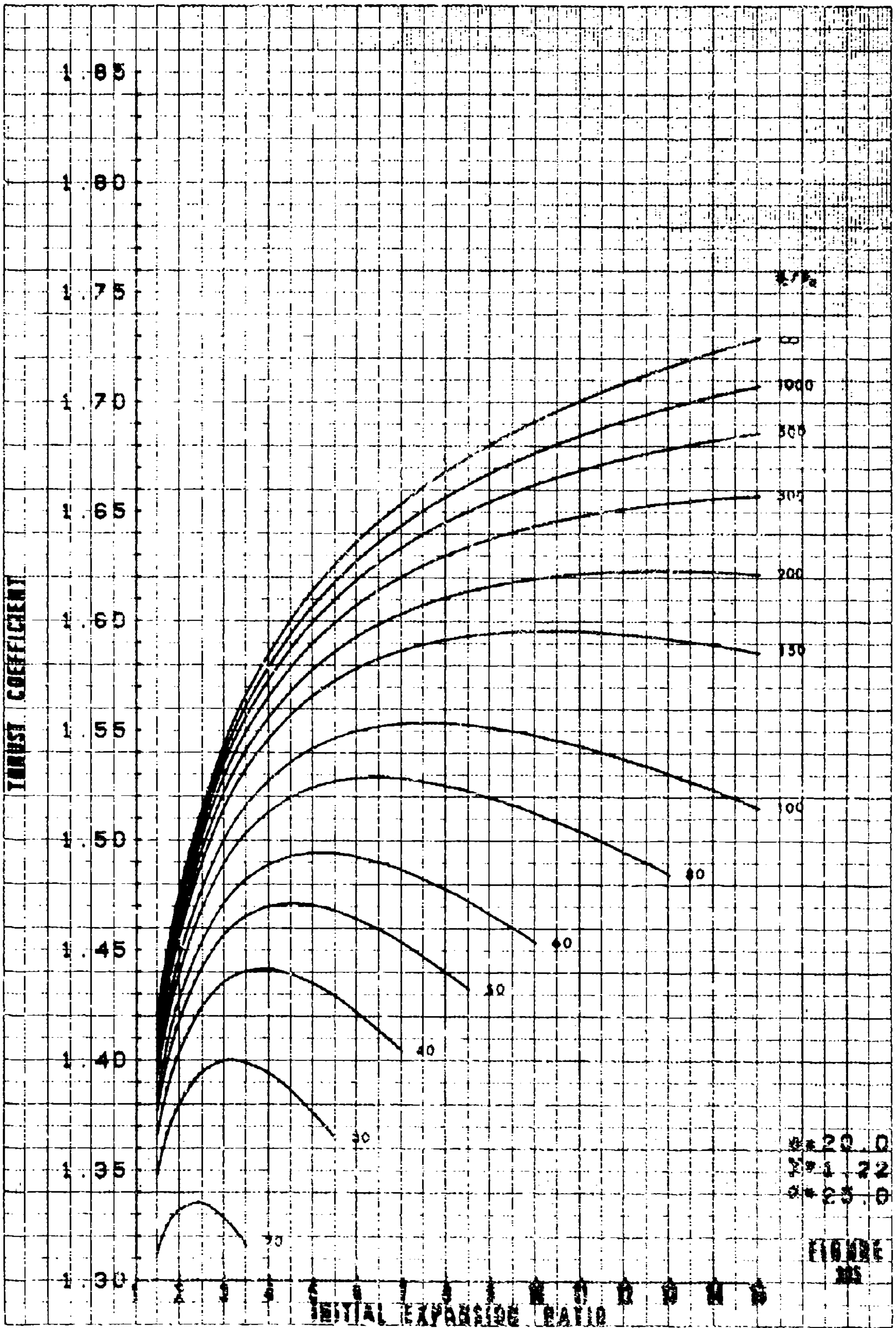


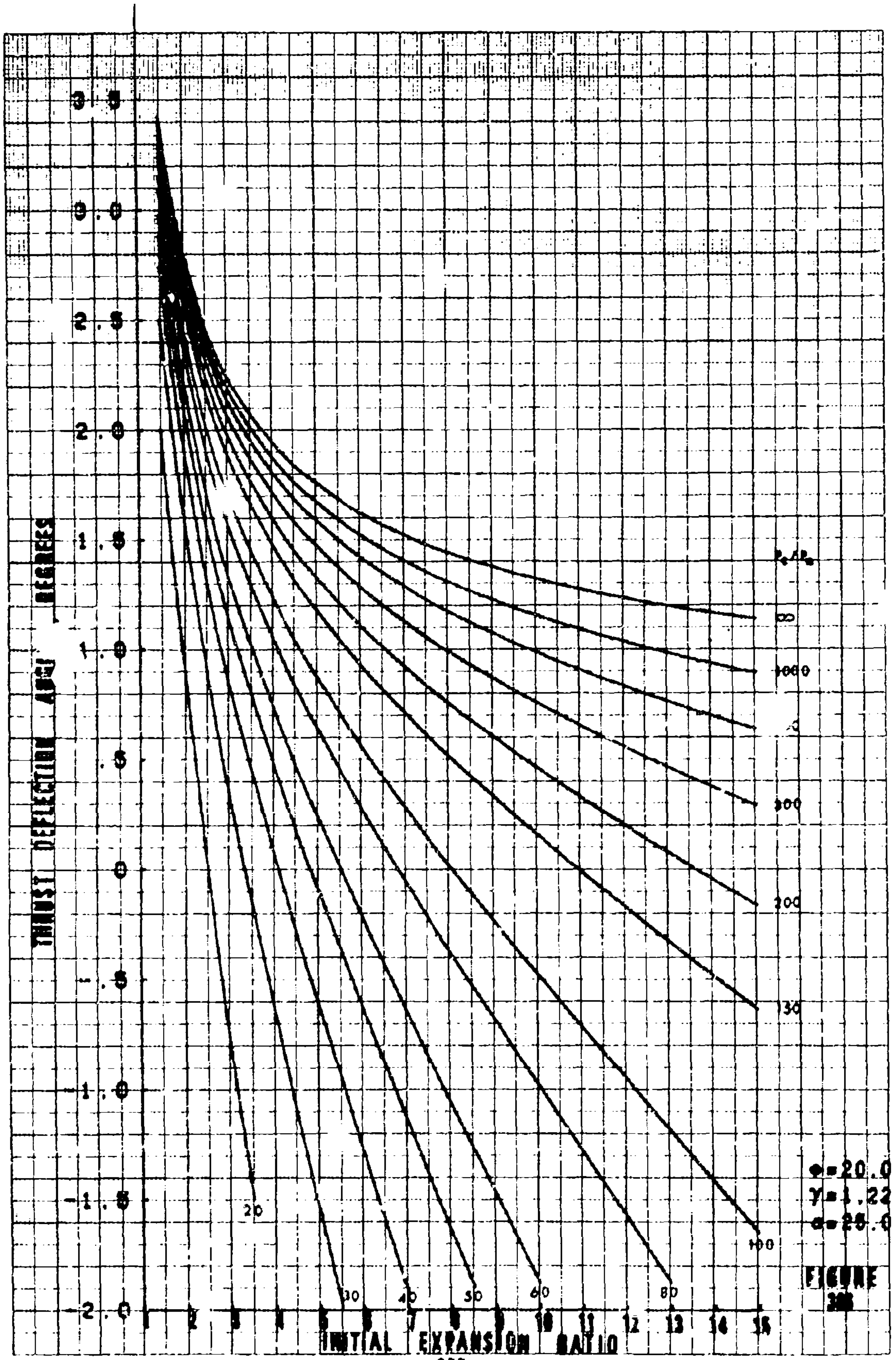
THRUST DEFLECTION ANGLE, DEGREES
2.0
1.5
1.0
.5
0
-.5
-1.0
-1.5
-2.0
INITIAL EXPANSION RATIO
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
P_c/P_a
∞
1000
500
300
200
150
100
80
60
50
40
30
20
FIGURE

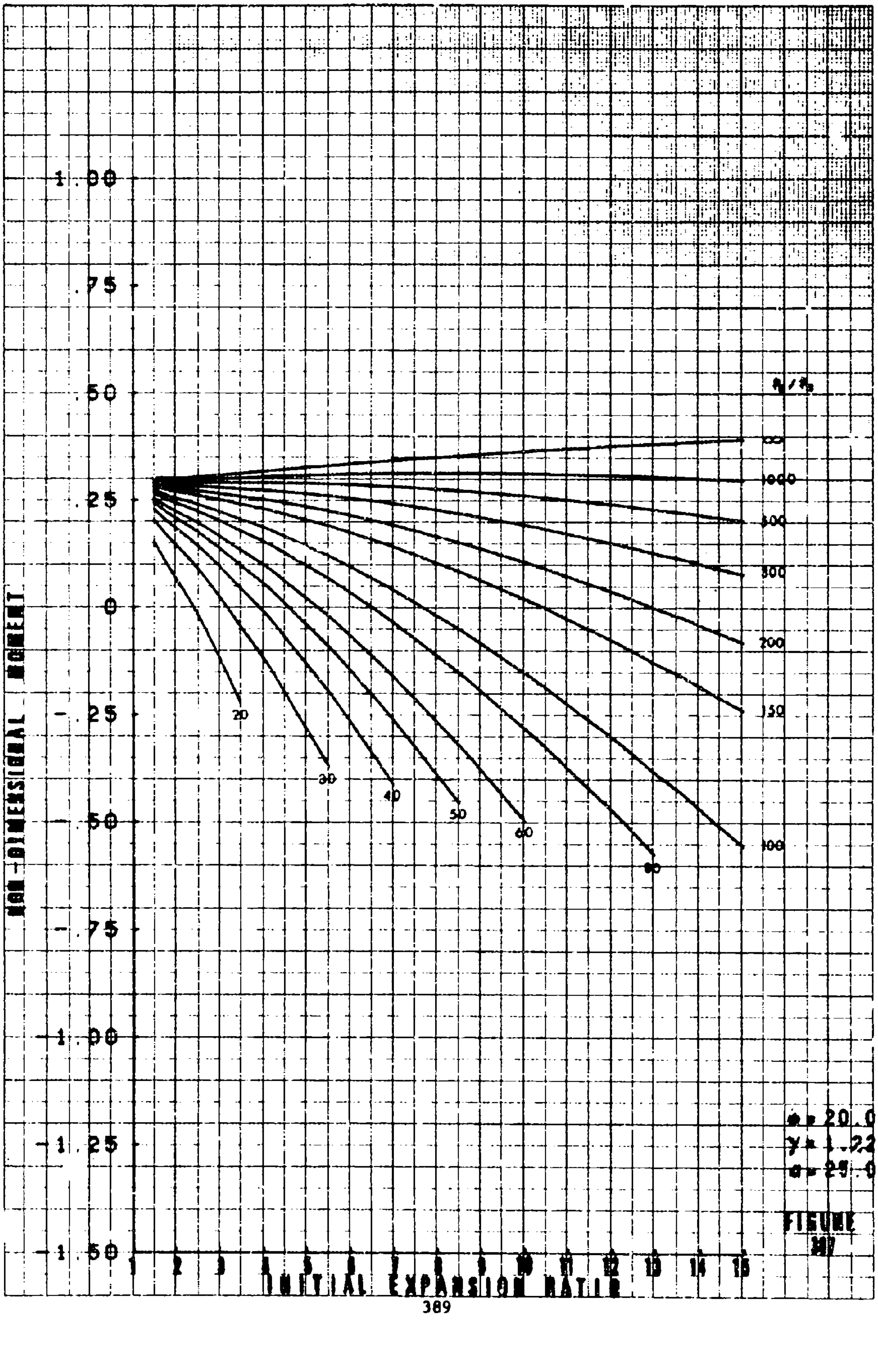


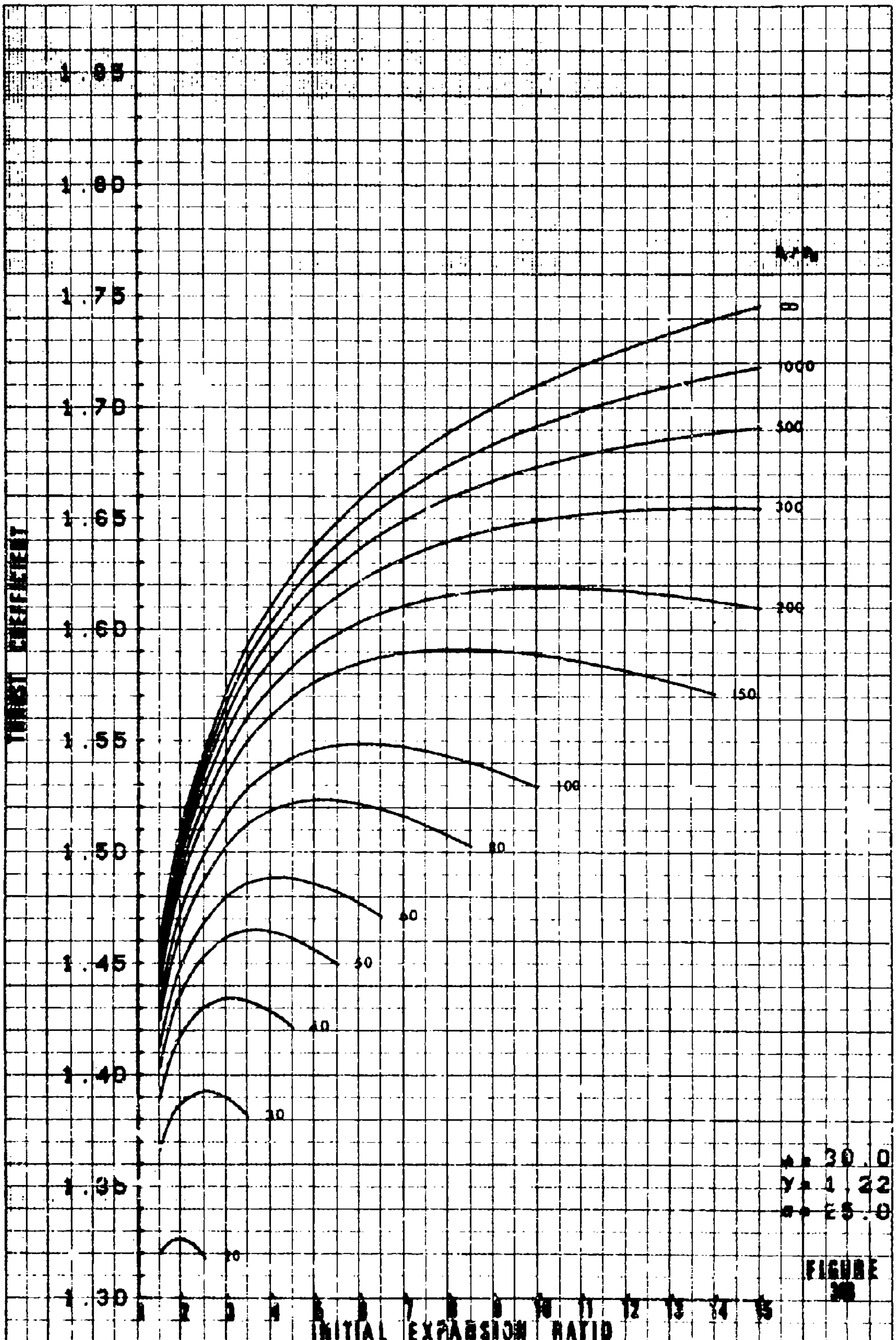
.20
.15
.10
.05
0
-.05
-.10
-.15
-.20
-.25
-.30
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
INITIAL EXPANSION RATIO
∞
1000
500
300
200
150
100
80
60
50
40
30
20
φ= 10.0
γ= 1.22
α= 25.0

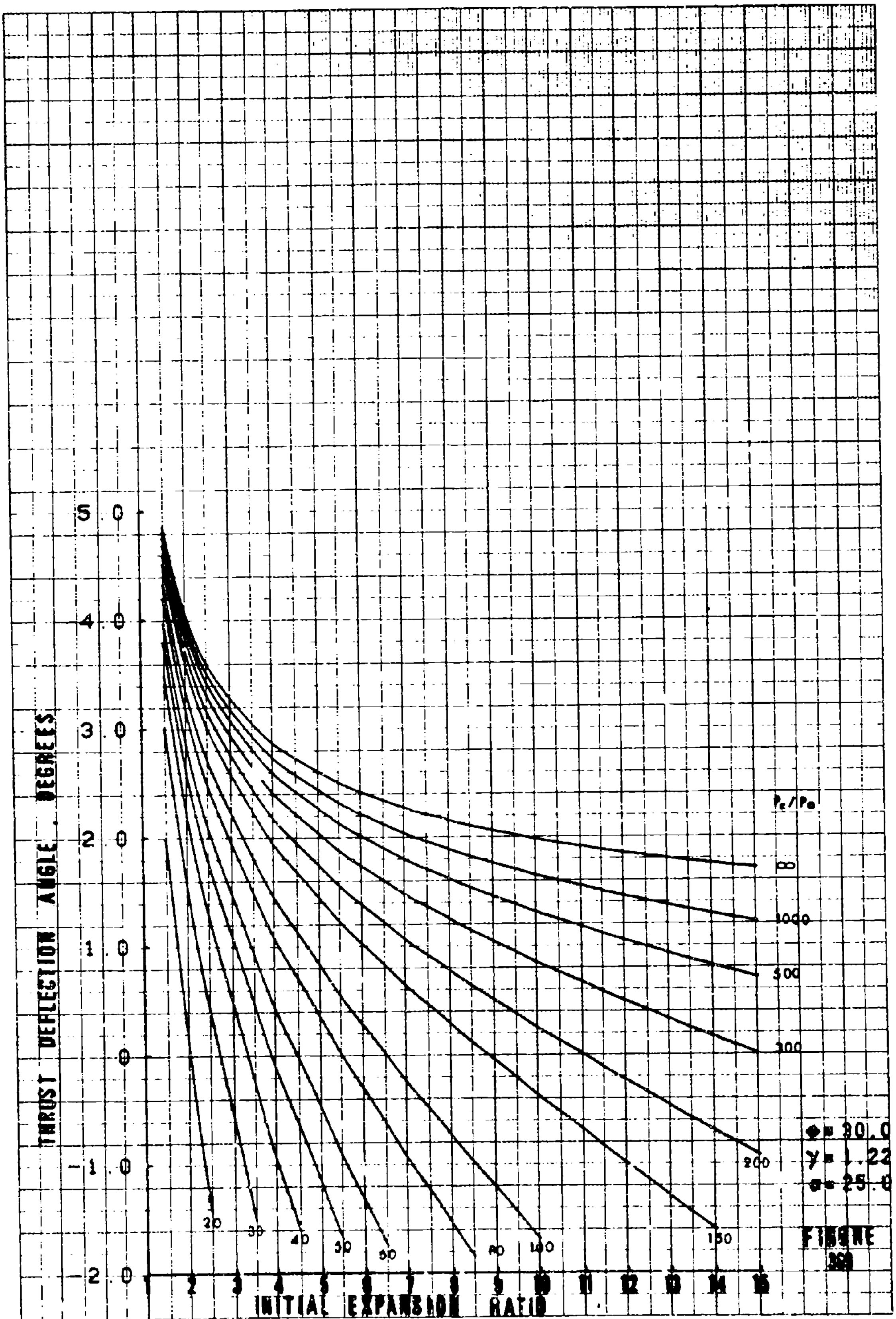
FIGURE 384

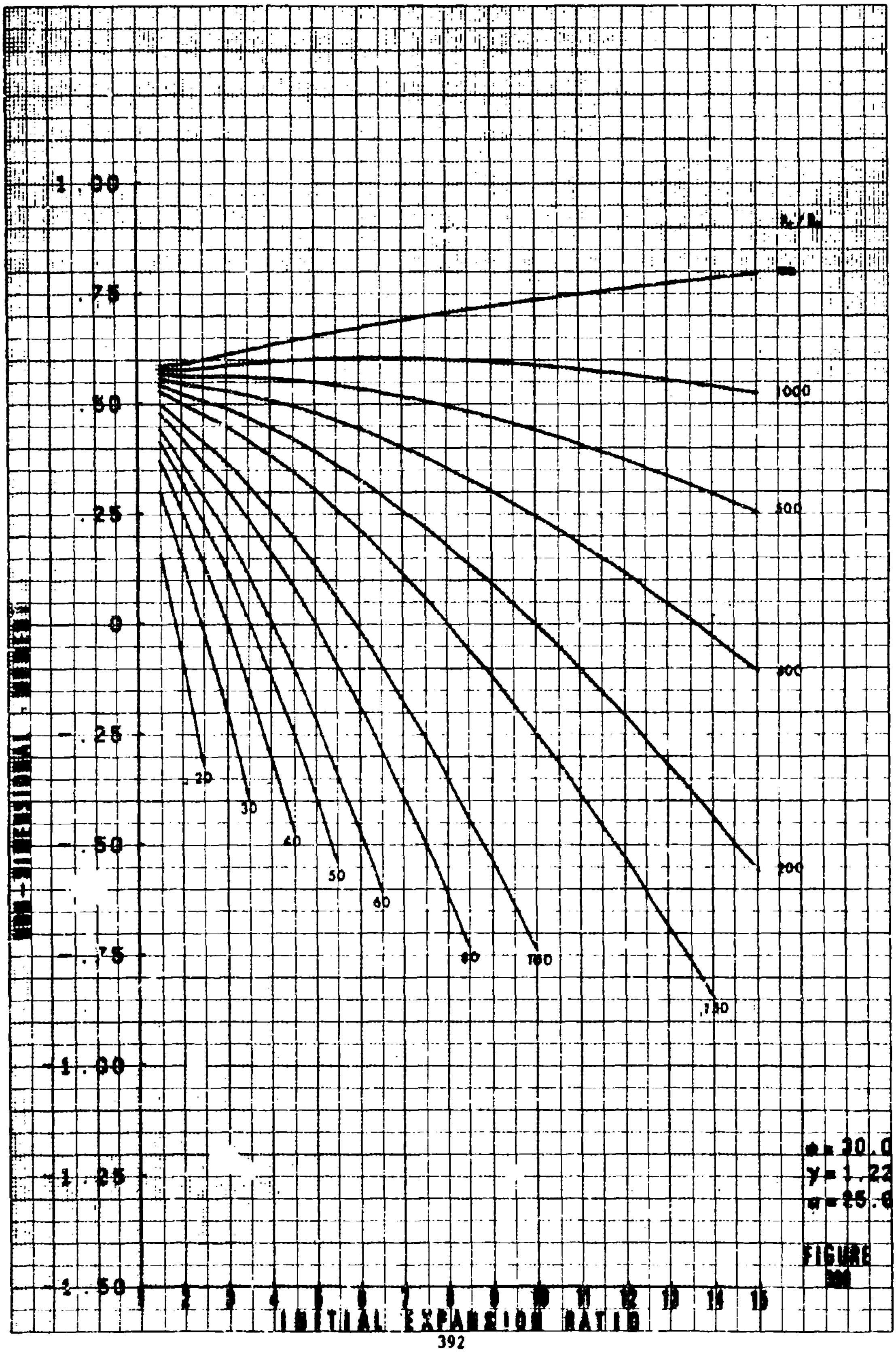

THRUST COEFFICIENT
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
INITIAL EXPANSION RATIO
∞
1000
500
300
200
150
100
80
60
50
40
30
20
20.0
1.22
25.0
FIGURE


THRUST DEFLECTION ANGLE, DEGREES
3.5
3.0
2.5
2.0
1.5
1.0
.5
0
-.5
-1.0
-1.5
-2.0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
INITIAL EXPANSION RATIO
P_c/P_a
∞
1000
300
200
100
80
60
50
40
30
20
ϕ = 20.0
γ = 1.22
FIGURE

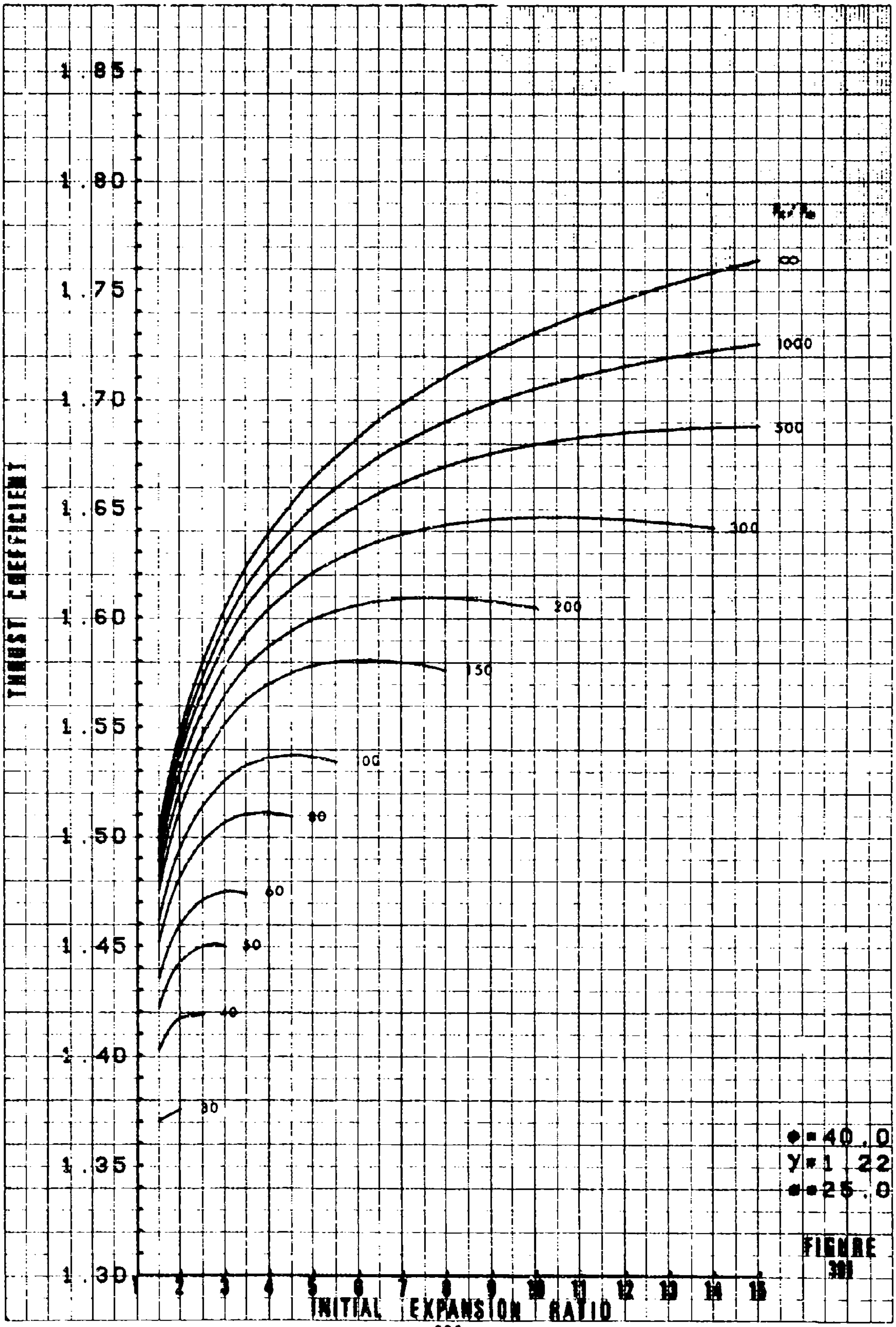

NON-DIMENSIONAL MOMENT
1.00
.75
.50
.25
0
-.25
-.50
-.75
-1.00
-1.25
-1.50
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
1000
500
300
200
150
100
20
30
40
50
60
80
φ = 20.0
γ = 1.22
FIGURE

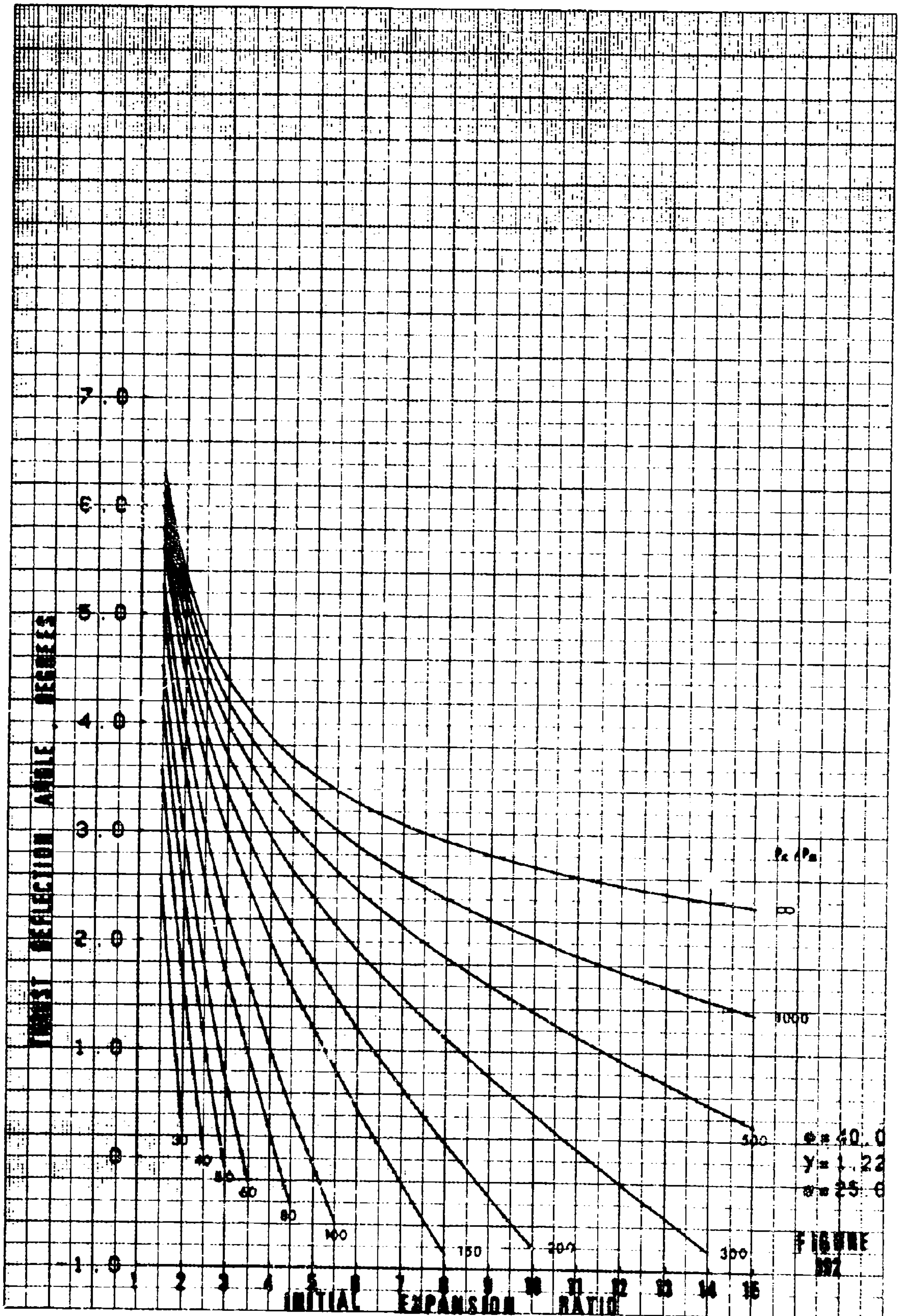

THRUST COEFFICIENT
INITIAL EXPANSION RATIO
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
1000
500
300
200
150
100
80
60
50
40
30
20
30.0
1.22
25.0
FIGURE

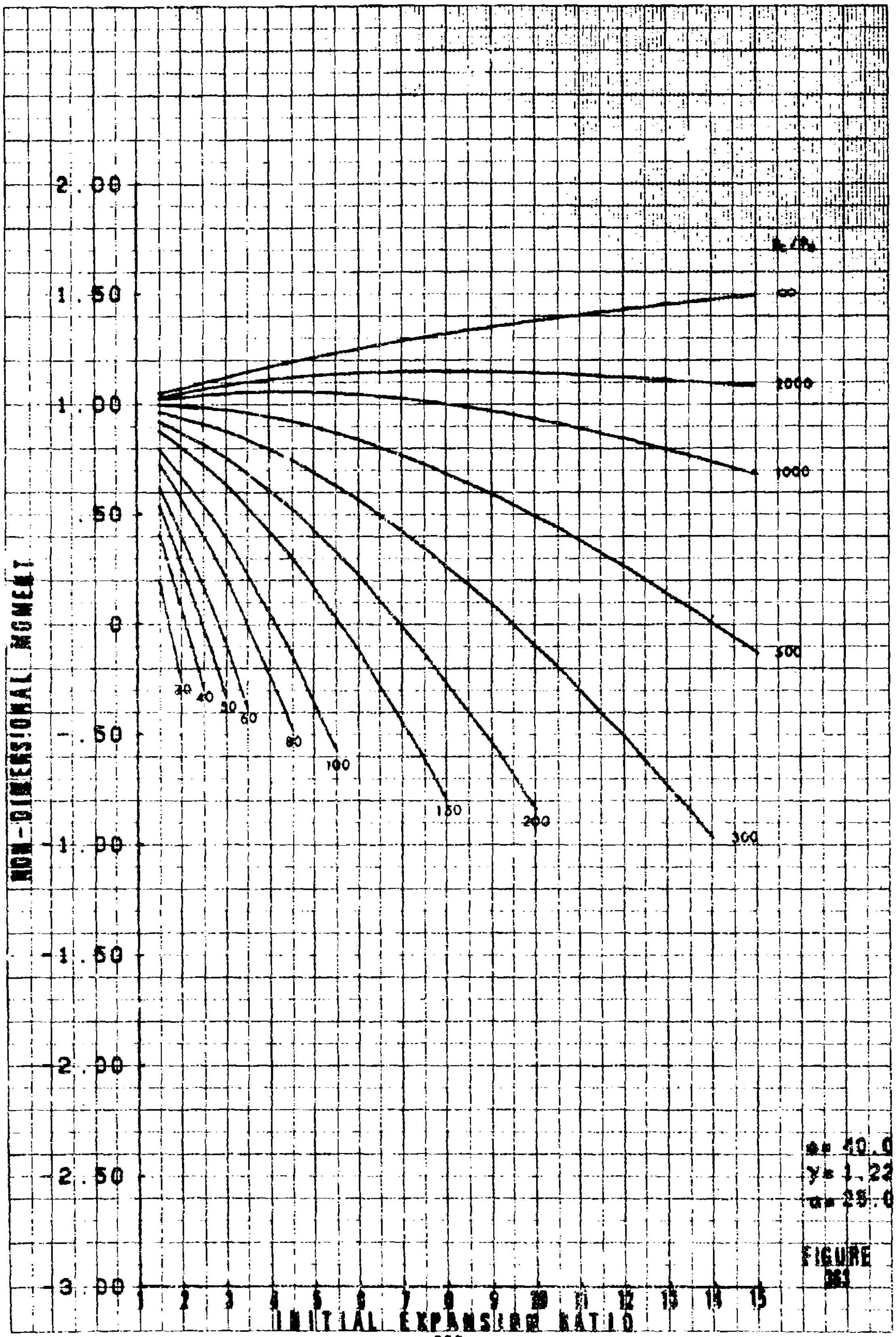

5.0
4.0
3.0
2.0
1.0
0
-1.0
-2.0
THRUST DEFLECTION ANGLE, DEGREES
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
INITIAL EXPANSION RATIO
P_c/P_a
∞
1000
500
300
200
150
100
80
60
50
40
30
20
ϕ = 30.0
γ = 1.22
α = 25.0
FIGURE

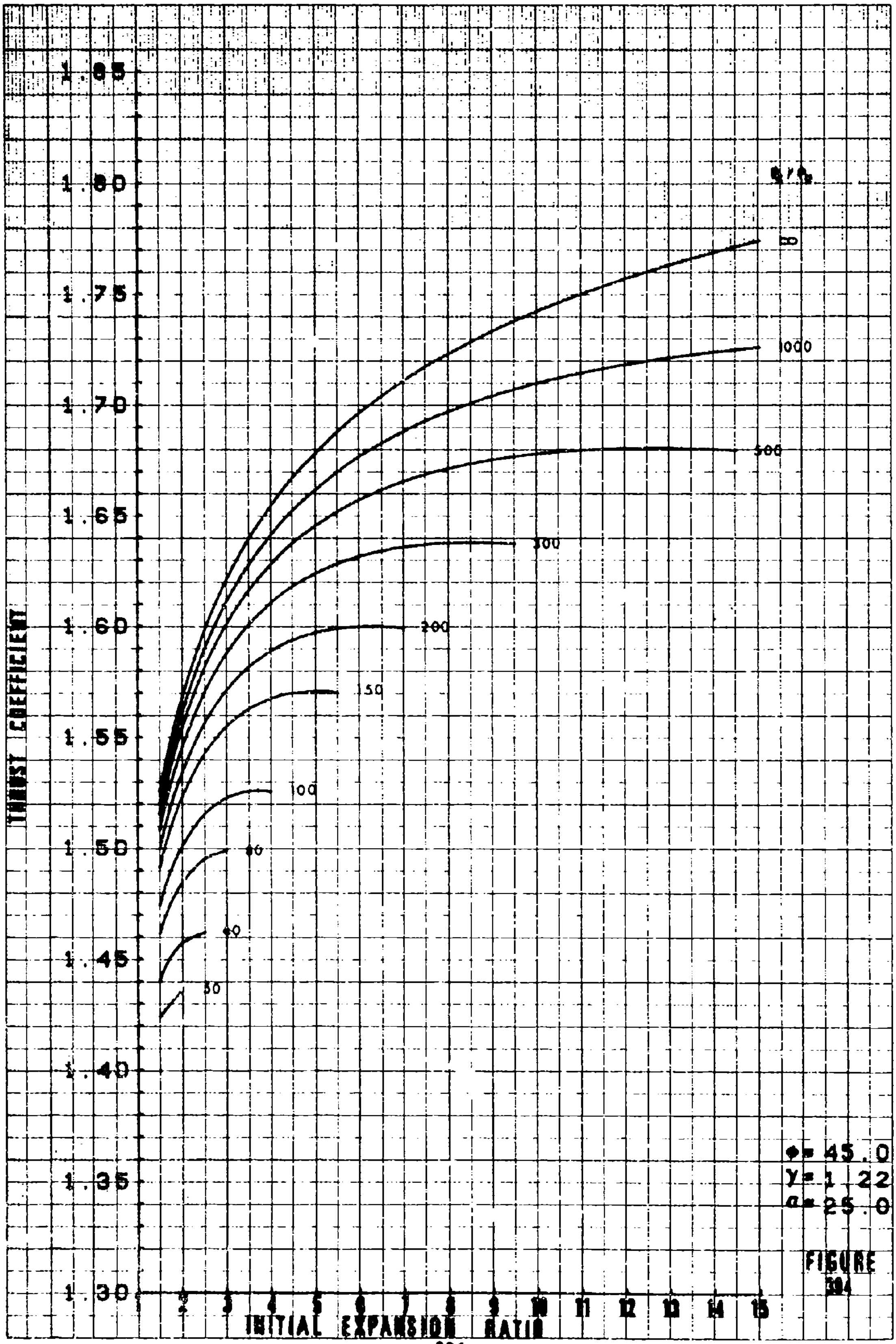


1.00
.75
.50
.25
0
-.25
-.50
-.75
-1.00
-1.25
-1.50
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
INITIAL EXPANSION RATIO
1000
500
300
200
150
100
80
60
50
40
30
20


THRUST COEFFICIENT
INITIAL EXPANSION RATIO
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
∞
1000
500
300
200
150
100
80
60
50
40
30
φ=40.0
γ=1.22
θ=25.0
FIGURE
381

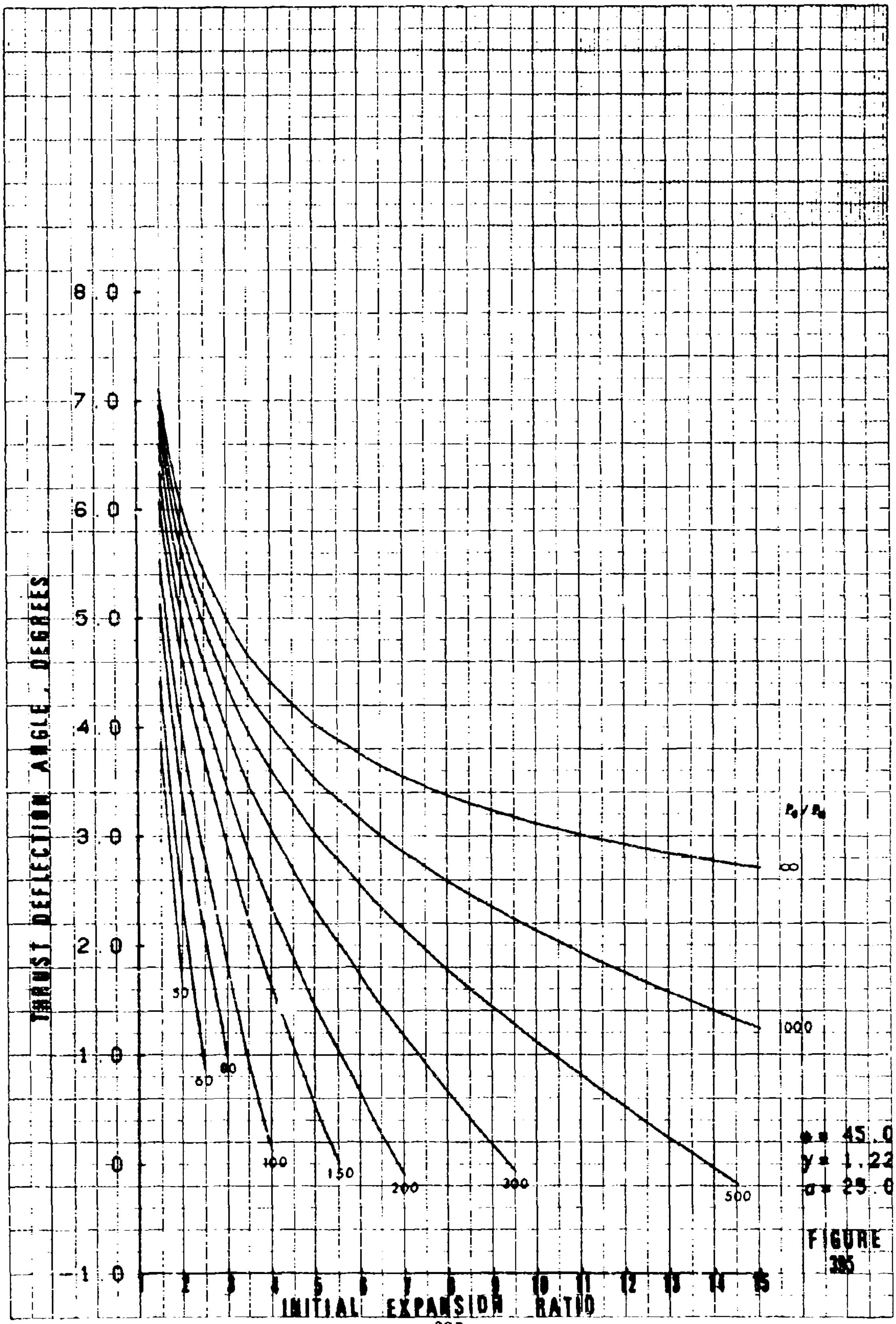

THRUST DEFLECTION ANGLE DEGREES
INITIAL EXPANSION RATIO
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
1.0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
30
40
50
60
80
100
150
200
300
500
1000
∞
Y = 1.22
FIGURE

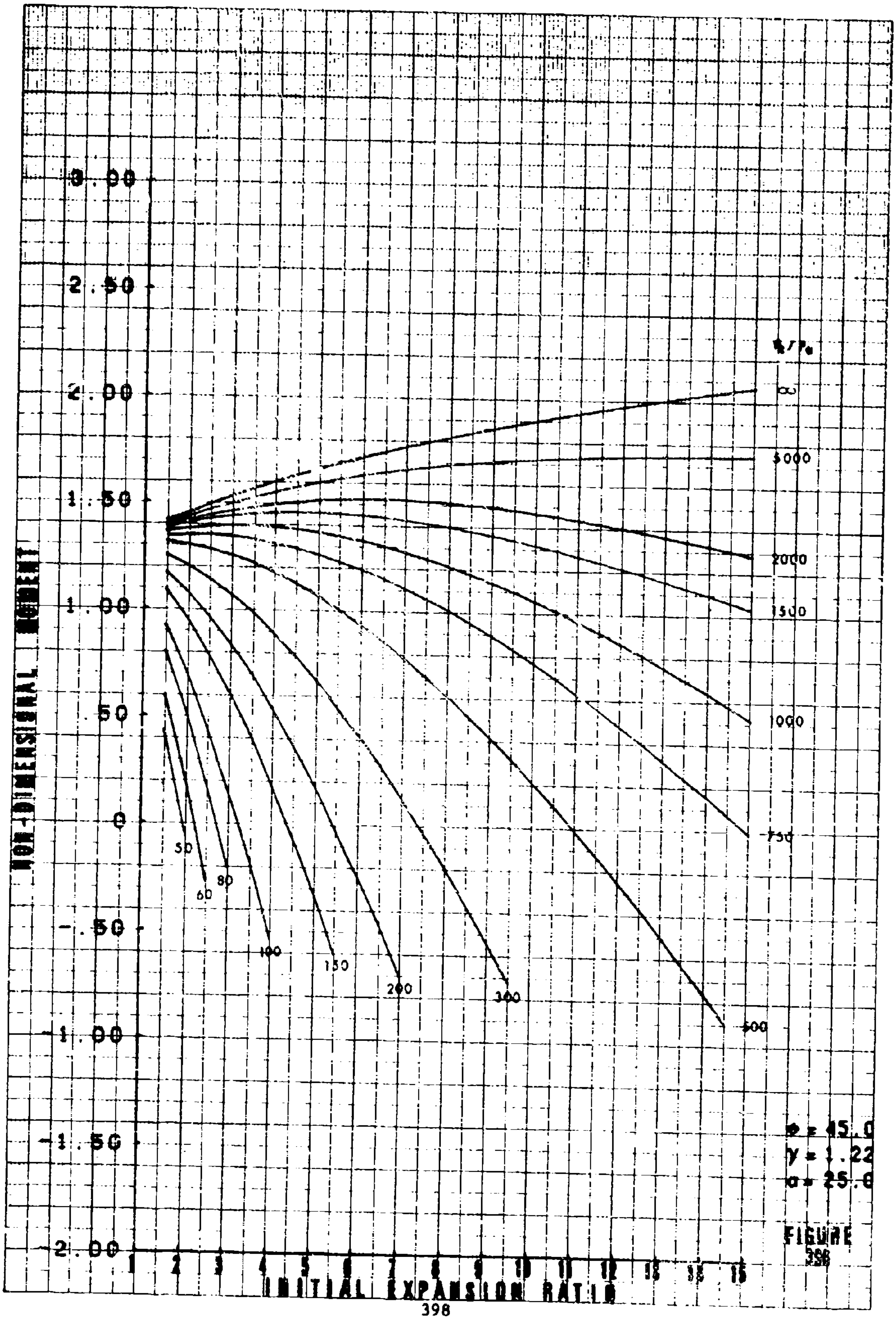

NON-DIMENSIONAL MOMENT
INITIAL EXPANSION RATIO
2.00
1.50
1.00
.50
0
-.50
-1.00
-1.50
-2.00
-2.50
-3.00
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
∞
2000
1000
500
300
200
150
100
80
60
50
40
30
y= 1.22
FIGURE

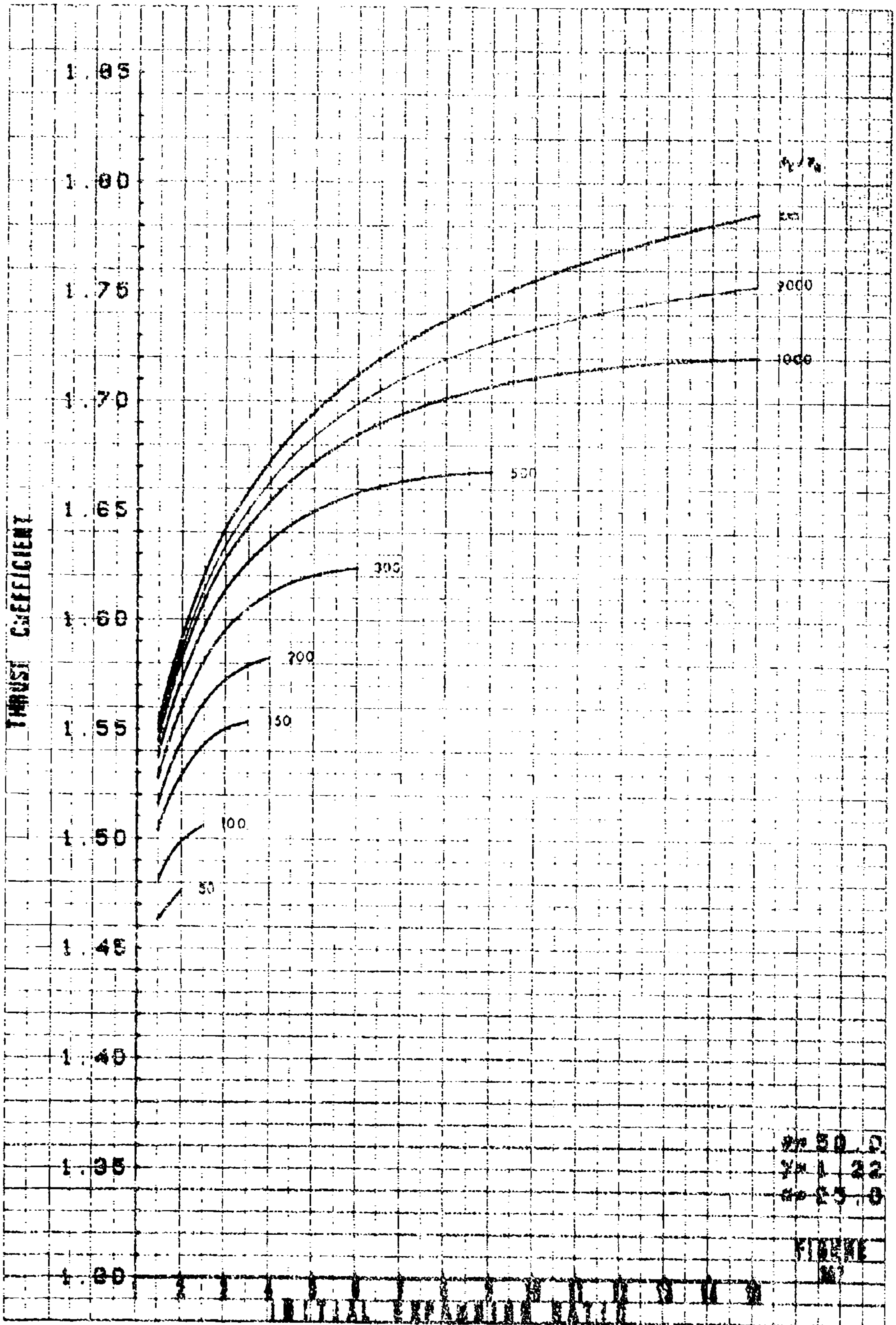


1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
THRUST COEFFICIENT
INITIAL EXPANSION RATIO
2 3 4 5 6 7 8 9 10 11 12 13 14 15
1000
500
300
200
150
100
80
40
30
φ= 45.0
γ= 1.22
α= 25.0

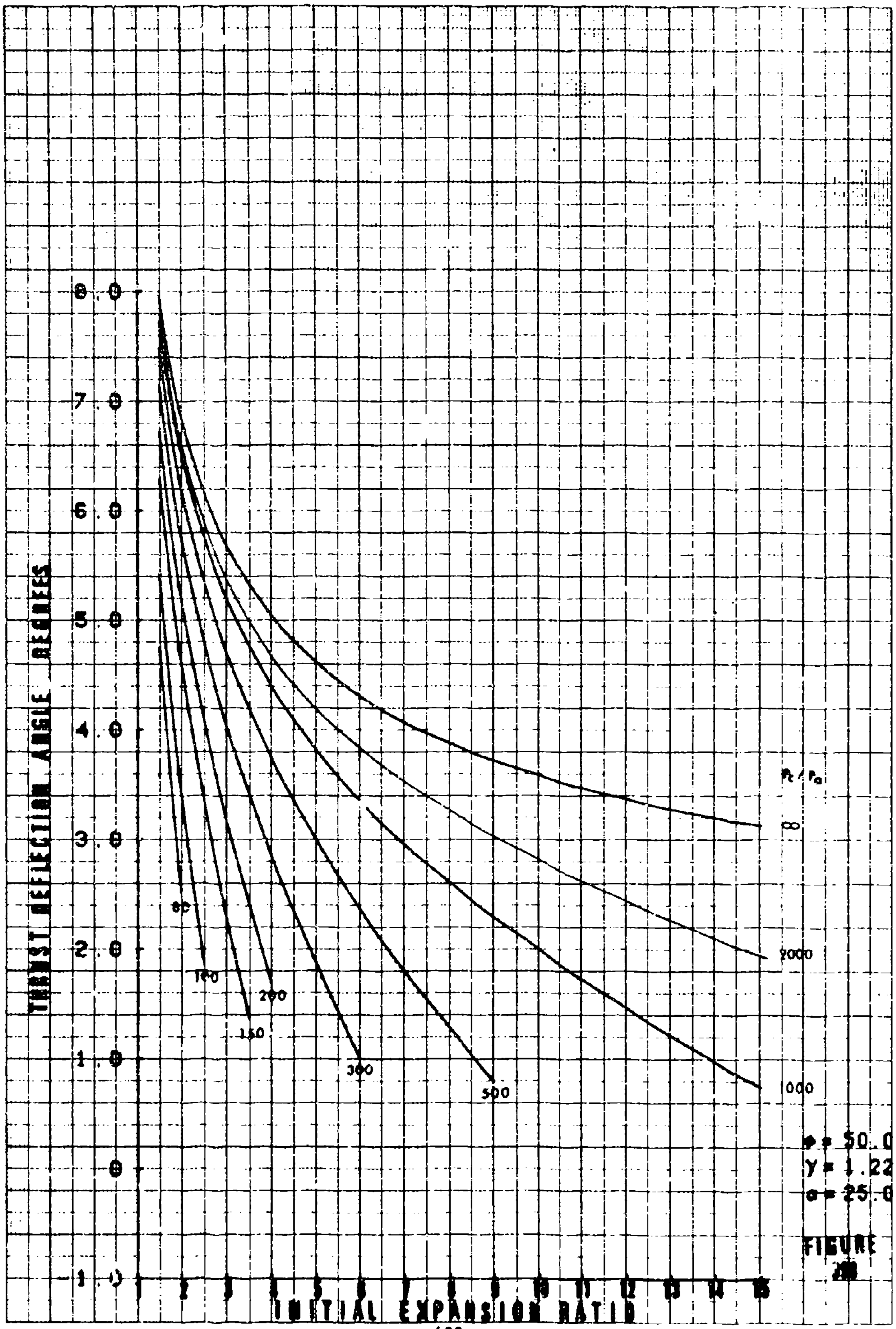
FIGURE 394

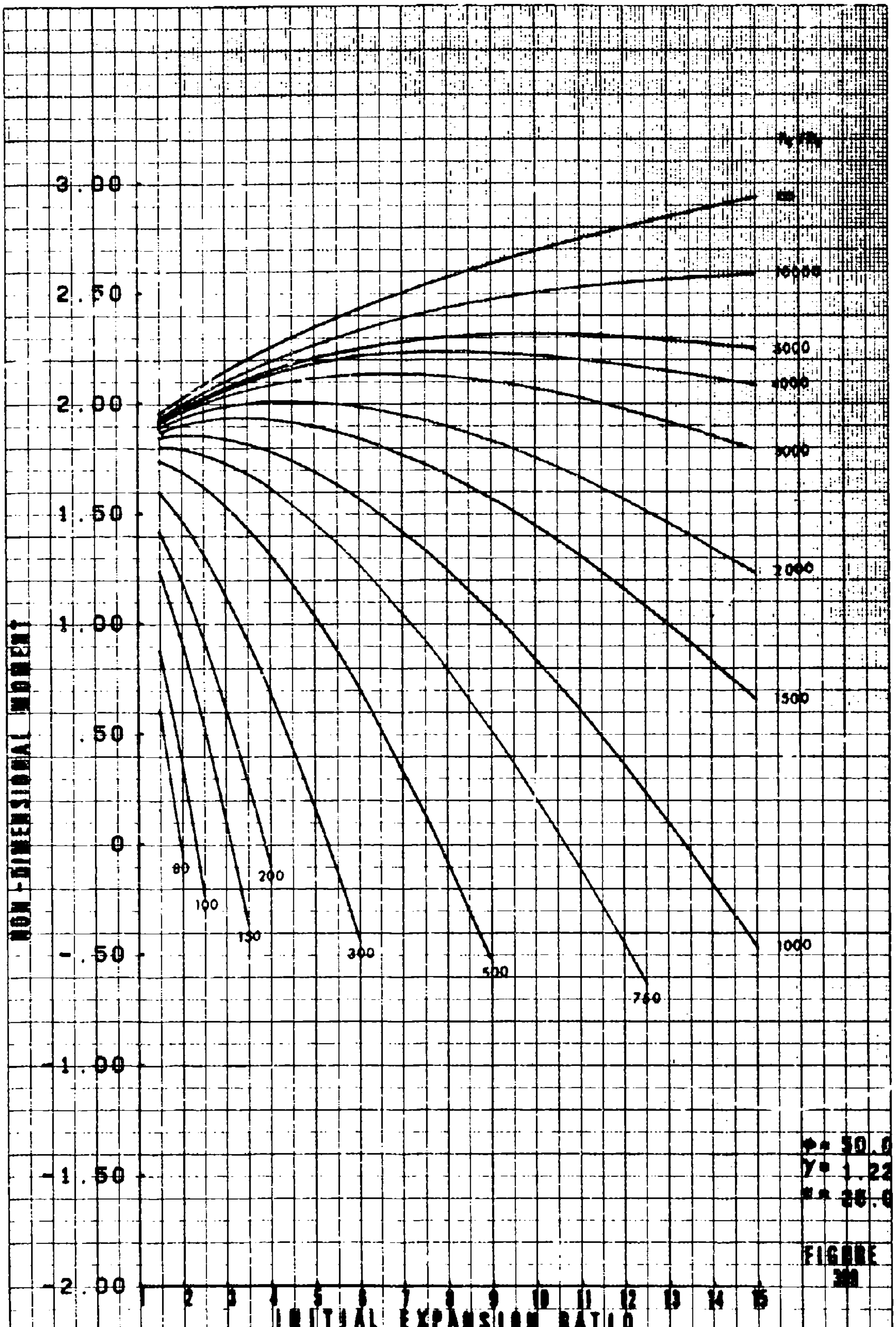

THRUST DEFLECTION ANGLE, DEGREES
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
-1.0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
INITIAL EXPANSION RATIO
P_0 / P_a
∞
1000
500
300
200
150
100
80
60
50
ϕ = 45.0
γ = 1.22
α = 25.0
FIGURE

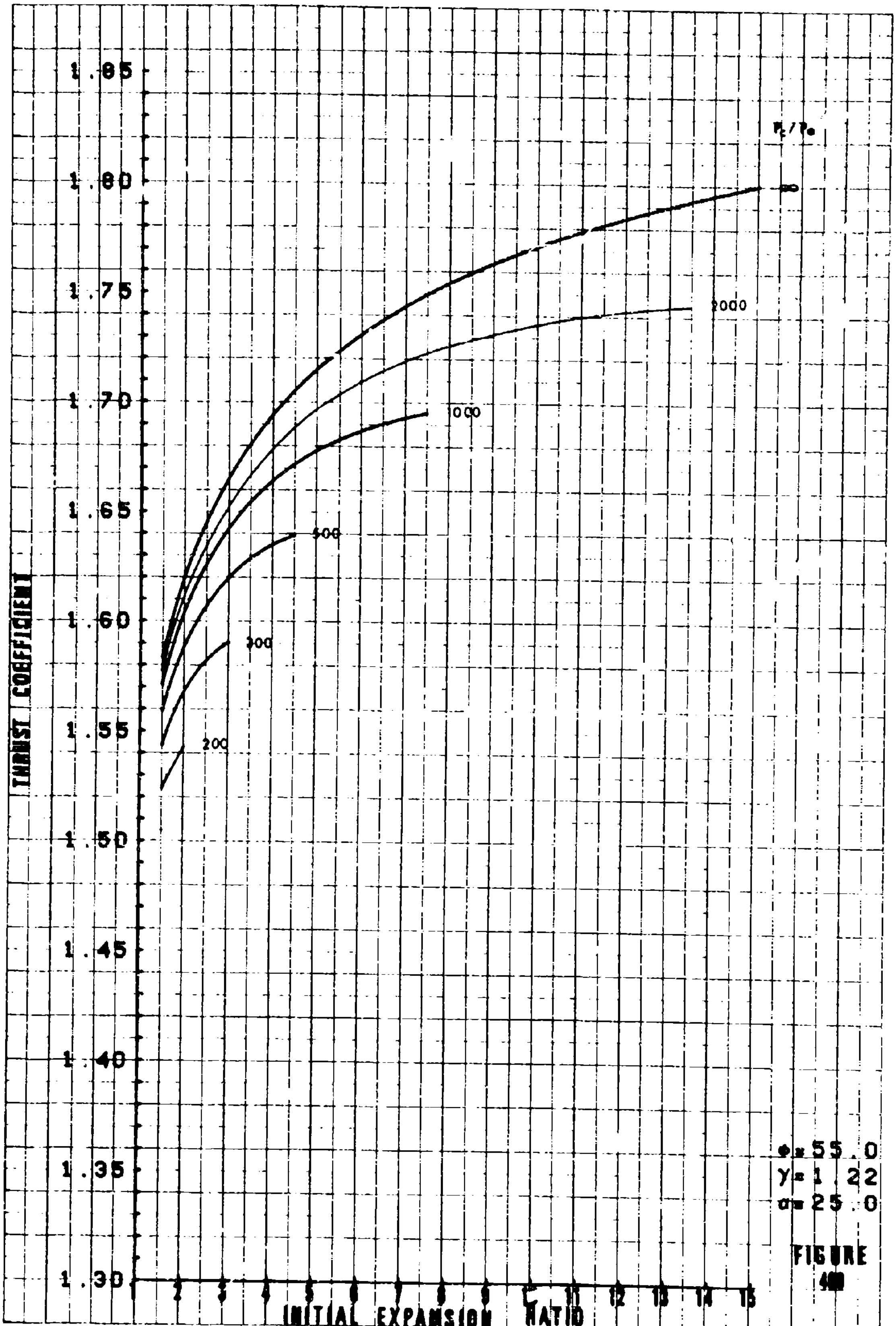

NON-DIMENSIONAL MOMENT
INITIAL EXPANSION RATIO
3.00
2.50
2.00
1.50
1.00
.50
0
-.50
-1.00
-1.50
-2.00
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
P_c/P_a
∞
5000
2000
1500
1000
750
500
300
200
150
100
80
60
50
ϕ = 45.0
γ = 1.22
α = 25.0
FIGURE 398

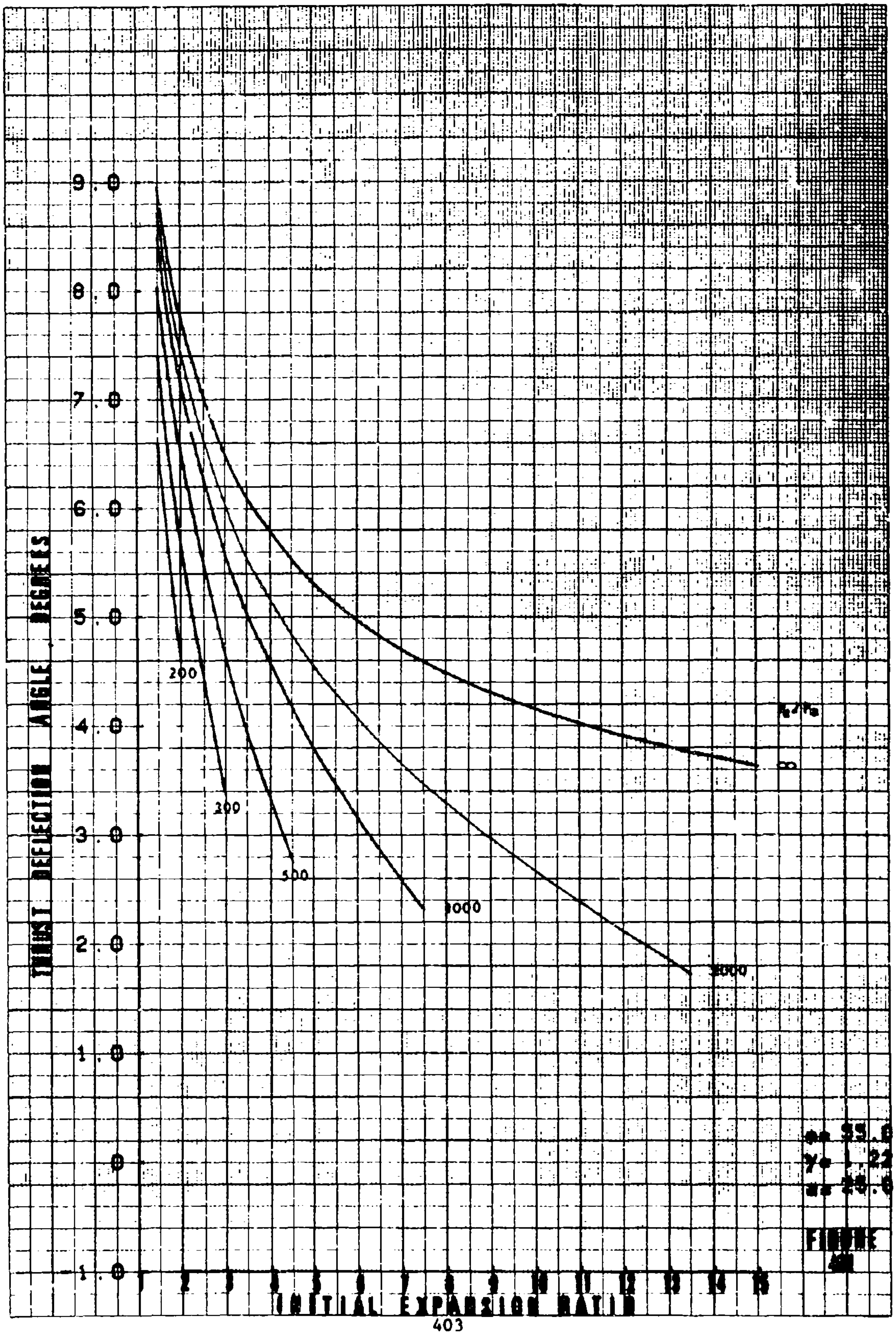


THRUST COEFFICIENT
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
2000
1000
500
300
200
150
100
50
γ = 1.22
INITIAL EXPANSION RATIO

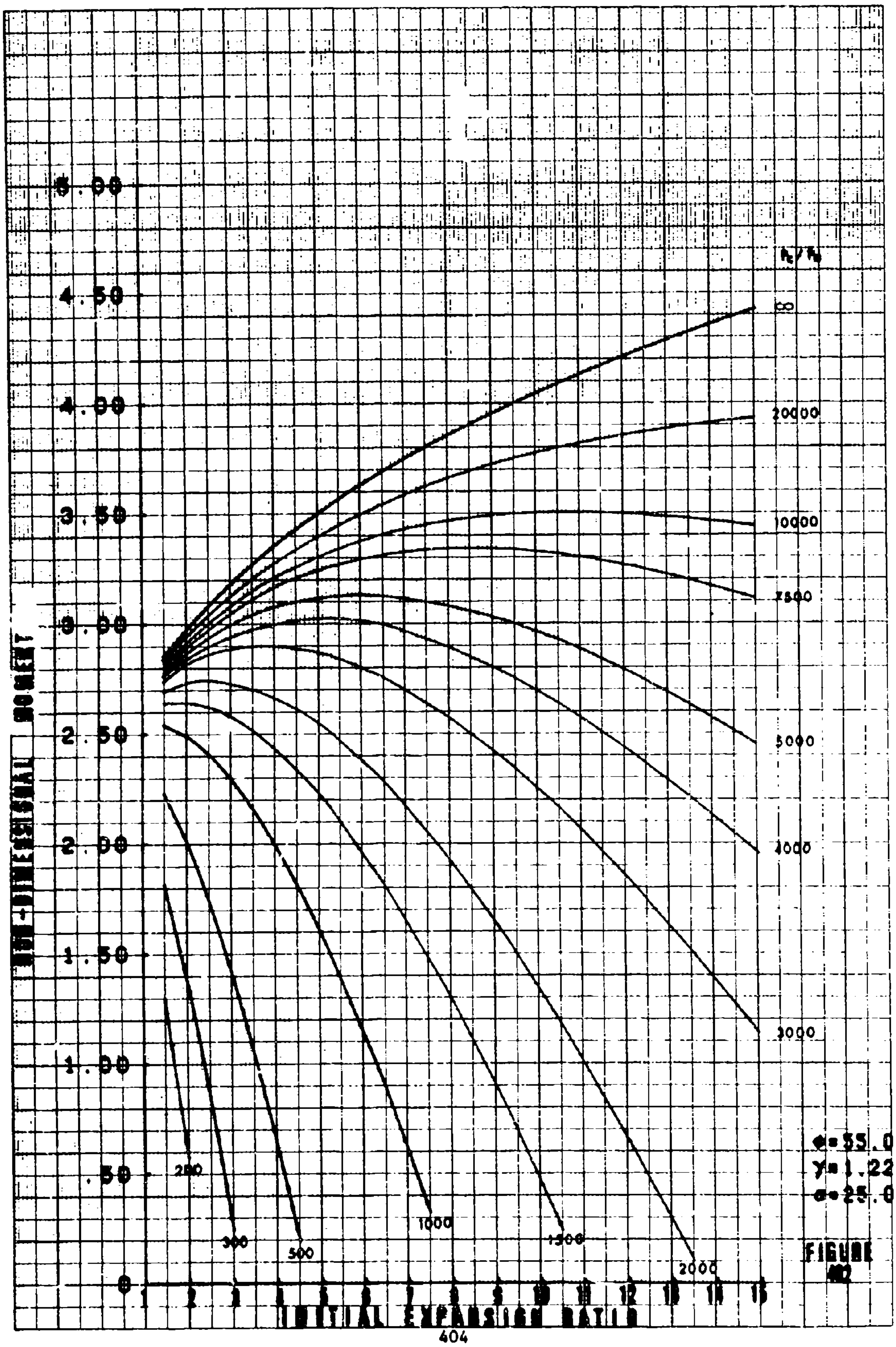

THRUST DEFLECTION ANGLE DEGREES
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
-1.0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
80
100
150
200
300
500
1000
2000
∞
P_c/P_a
φ = 50.0
γ = 1.22
α = 25.0
FIGURE


3.00
2.50
2.00
1.50
1.00
.50
0
-.50
-1.00
-1.50
-2.00
NON-DIMENSIONAL MOMENT
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
10000
2000
1500
1000
750
500
300
200
150
100
80

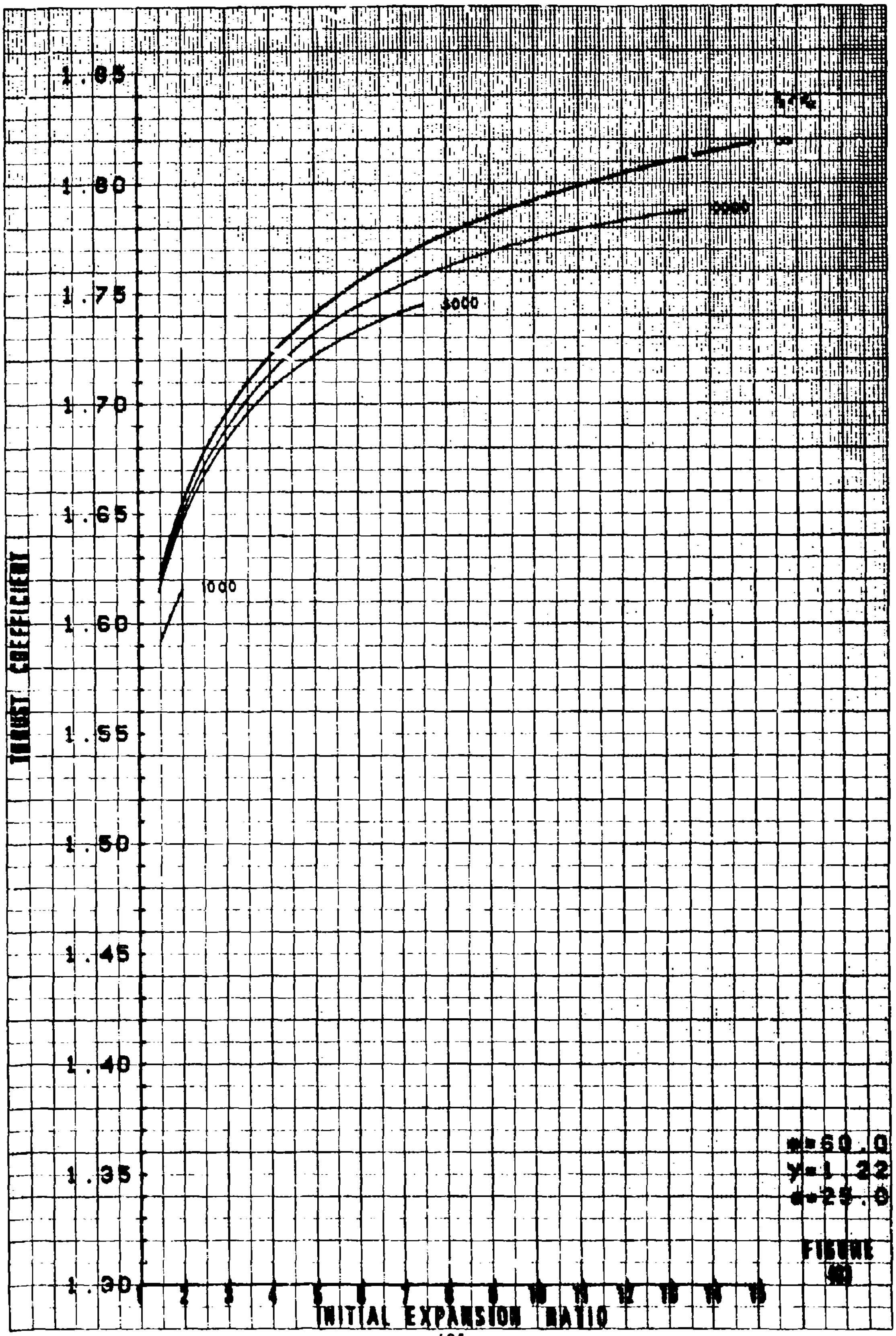

THRUST COEFFICIENT
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
P_c/P_e
∞
2000
1000
500
300
200
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
INITIAL EXPANSION RATIO
φ = 55.0
γ = 1.22
α = 25.0
FIGURE
400

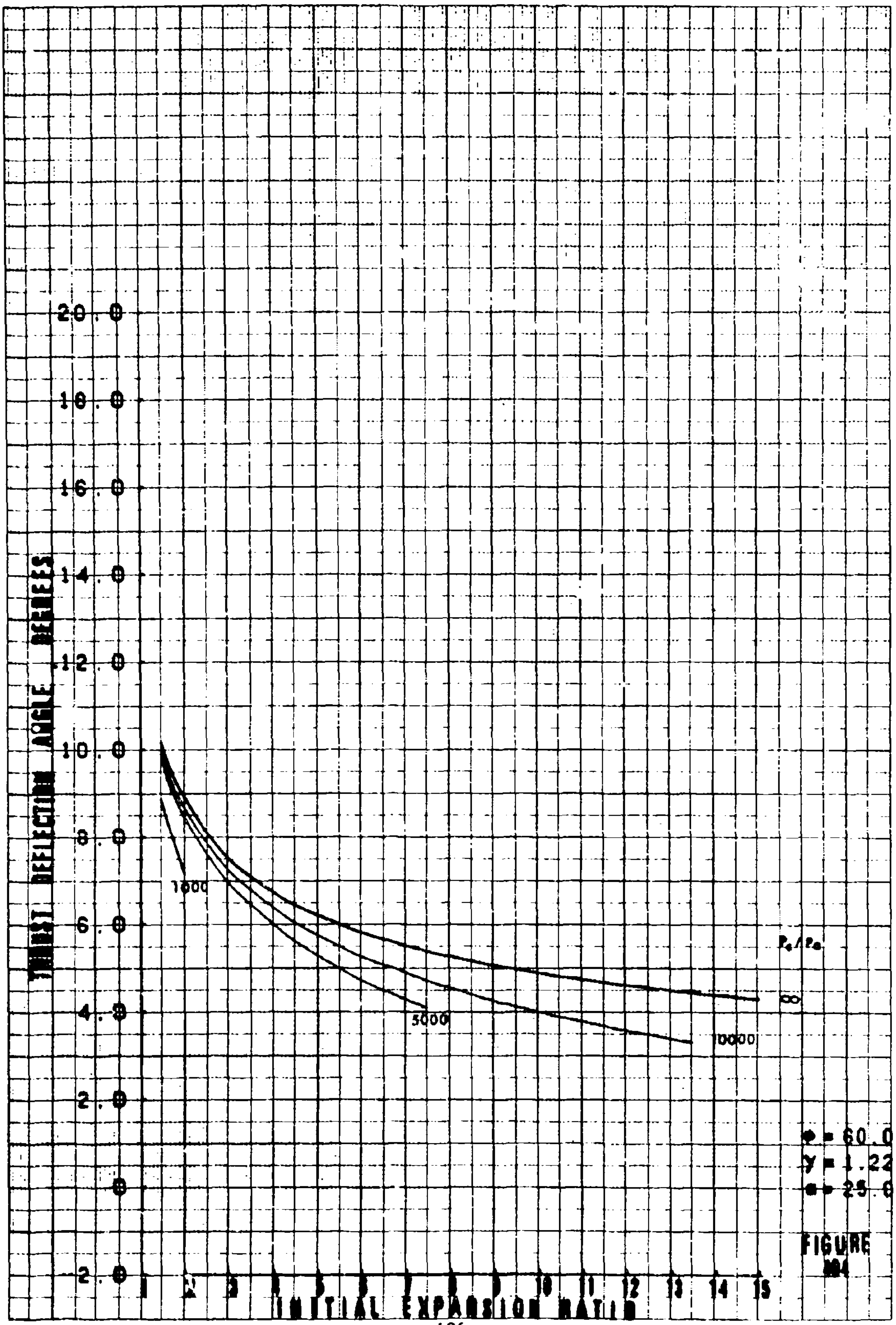


THRUST DEFLECTION ANGLE DEGREES
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
200
300
500
1000
2000
∞
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
INITIAL EXPANSION RATIO
FIGURE



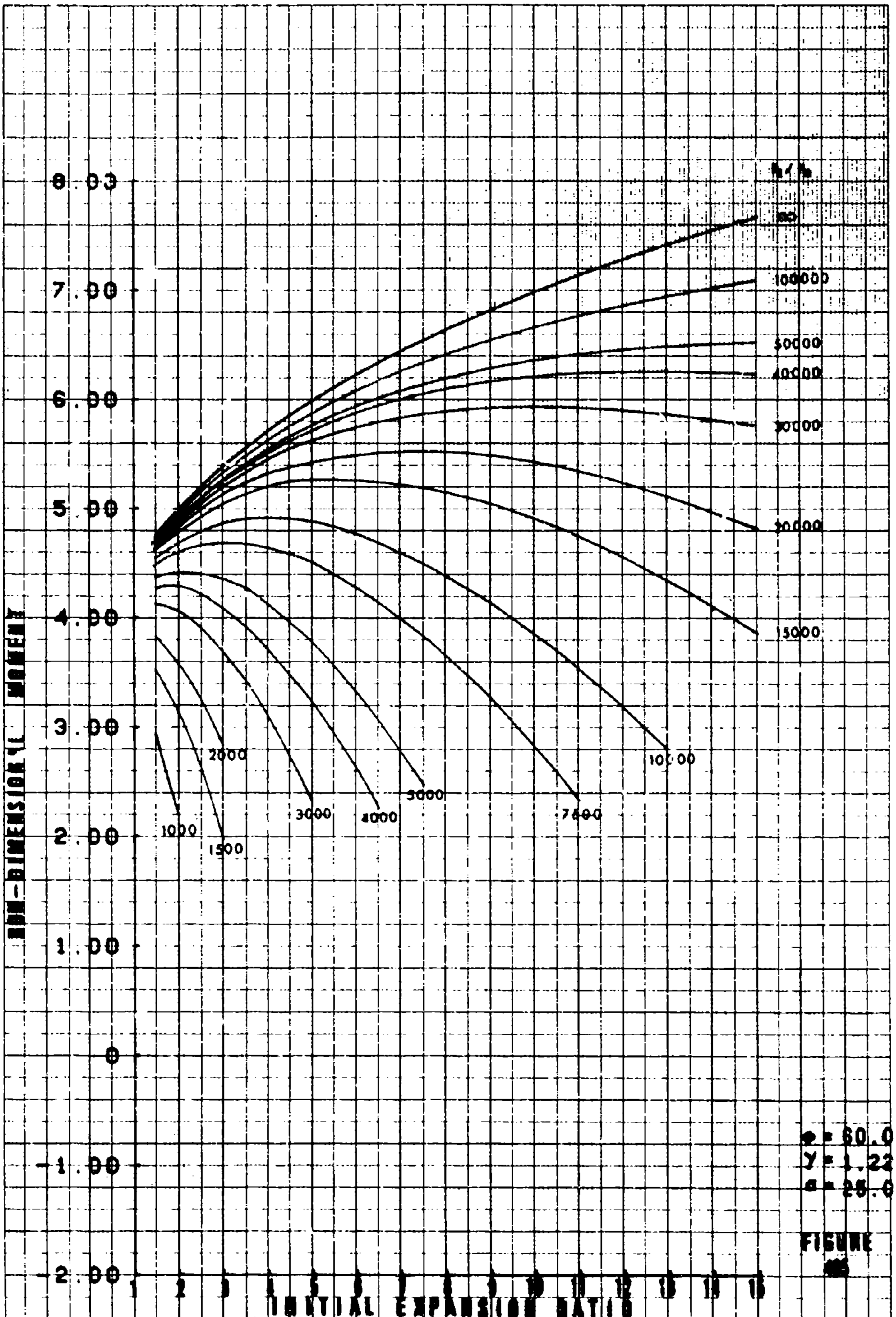
NON-DIMENSIONAL MOMENT
INITIAL EXPANSION RATIO
h_c/h_0
∞
20000
10000
7500
5000
4000
3000
2000
1500
1000
500
300
200
φ=35.0
γ=1.22
α=25.0
FIGURE 402


1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
THRUST COEFFICIENT
INITIAL EXPANSION RATIO
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
1000
3000
5000
∞
=60.0
=1.22
=25.0
FIGURE

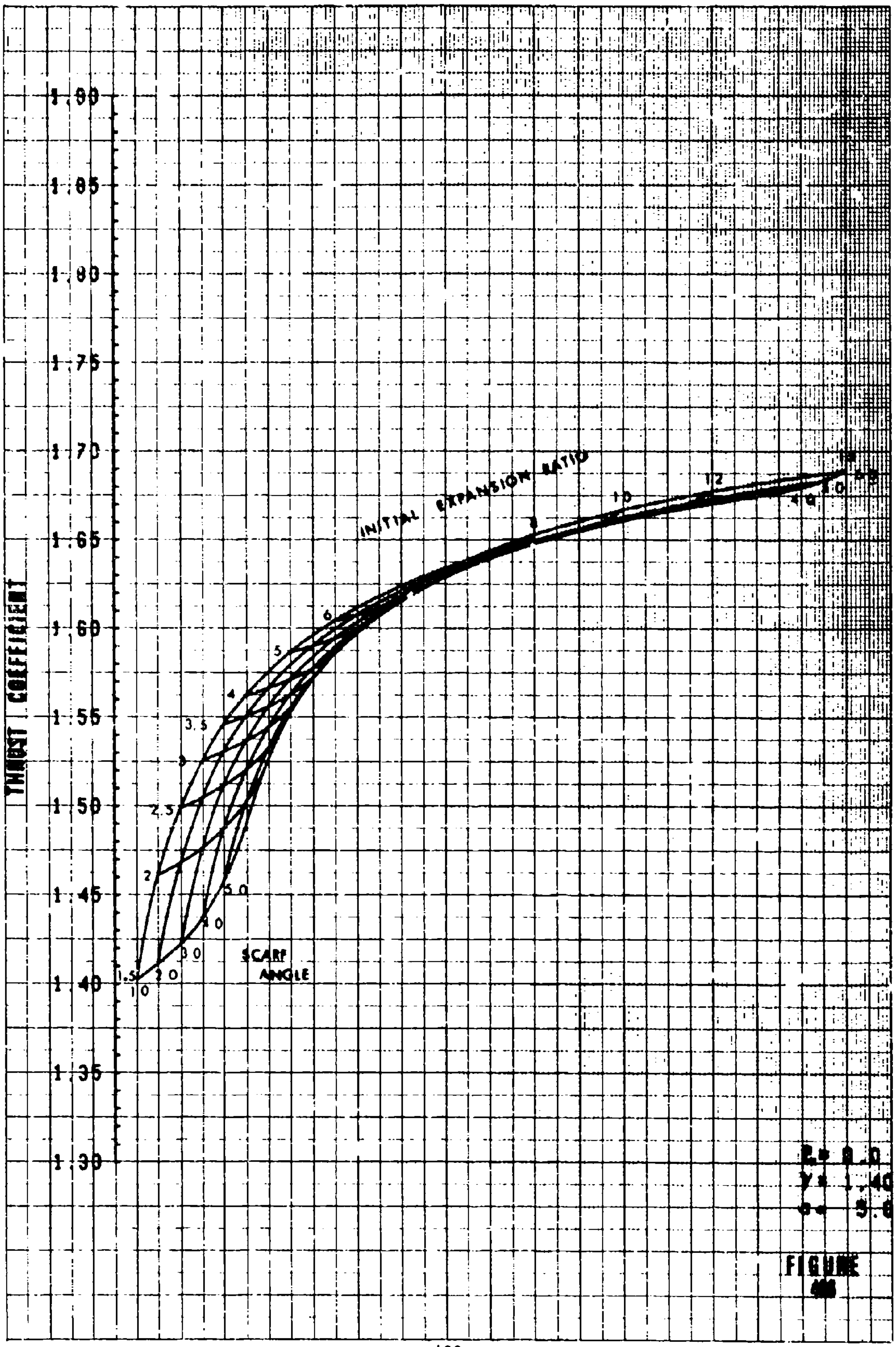


THRUST DEFLECTION ANGLE DEGREES
20.0
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0
2.0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
1000
5000
10000
∞
P_c/P_a
Φ = 60.0
γ = 1.22
α = 25.0

FIGURE 404



NON-DIMENSIONAL MOMENT
INITIAL EXPANSION RATIO
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0
-1.00
-2.00
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
100000
50000
40000
30000
20000
15000
10000
7500
5000
4000
3000
2000
1500
1000
FIGURE



THRUST COEFFICIENT
1.90
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
INITIAL EXPANSION RATIO
SCARF ANGLE
1.5
2
2.5
3
3.5
4
5
6
8
10
12
10
20
30
40
50
FIGURE

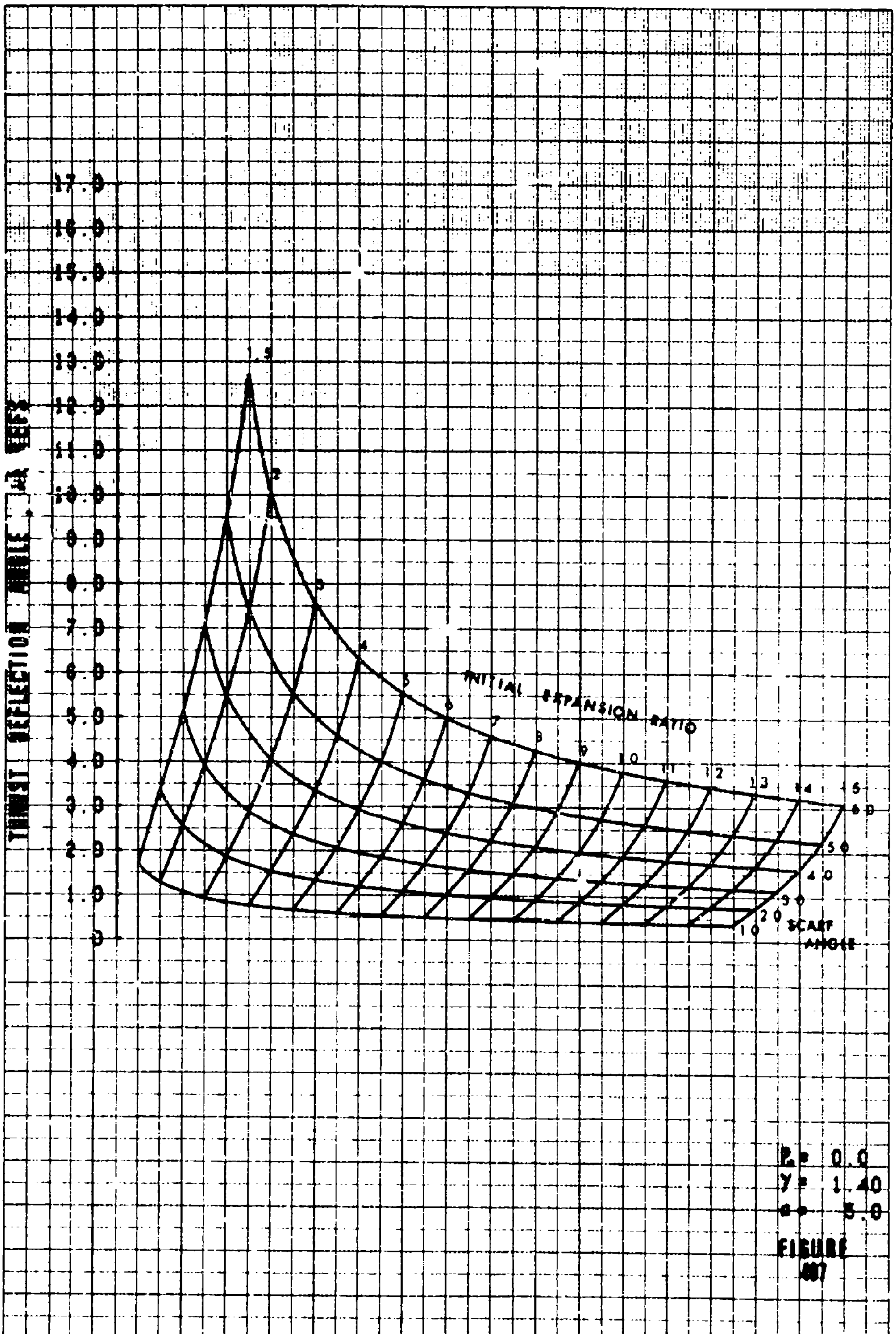
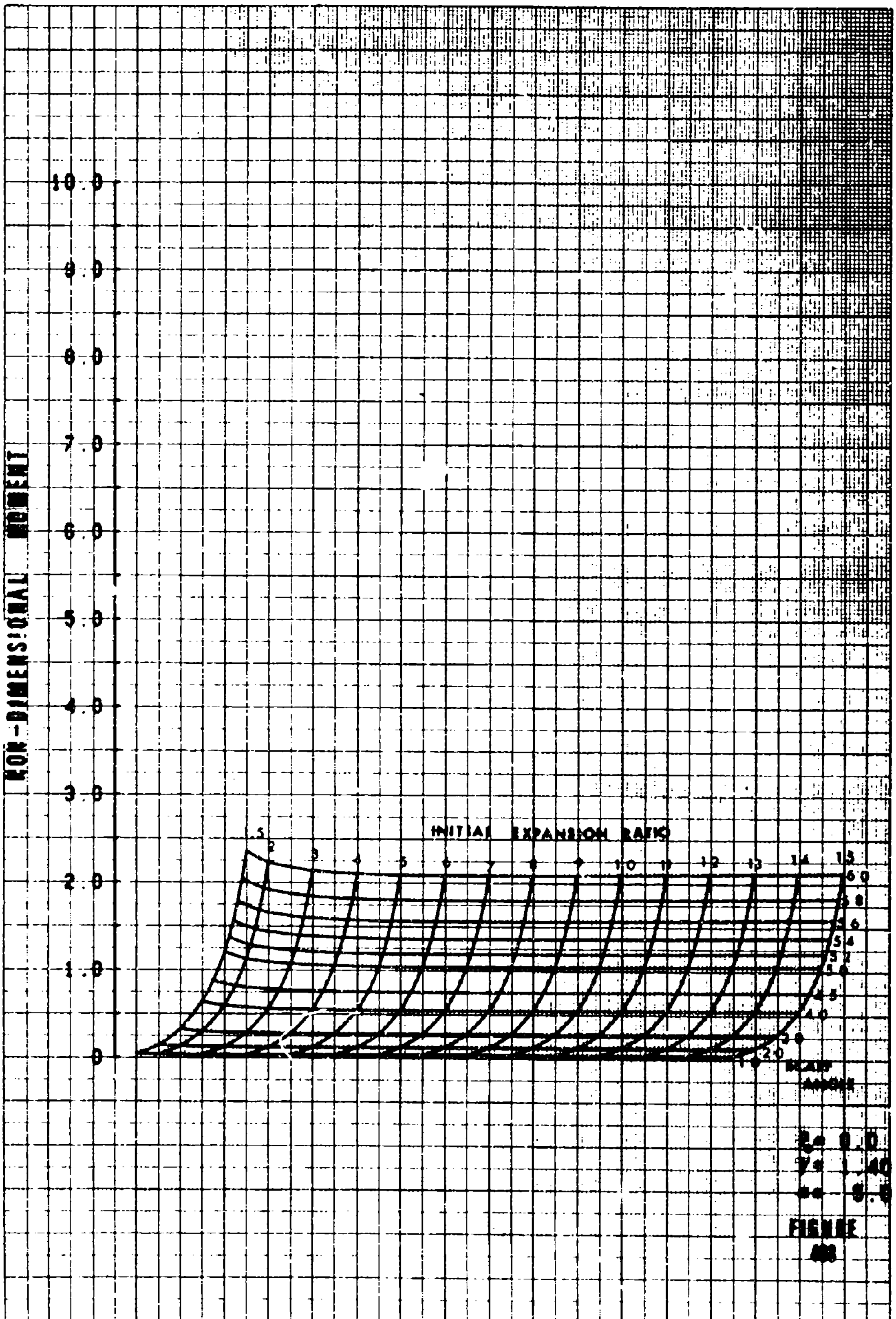
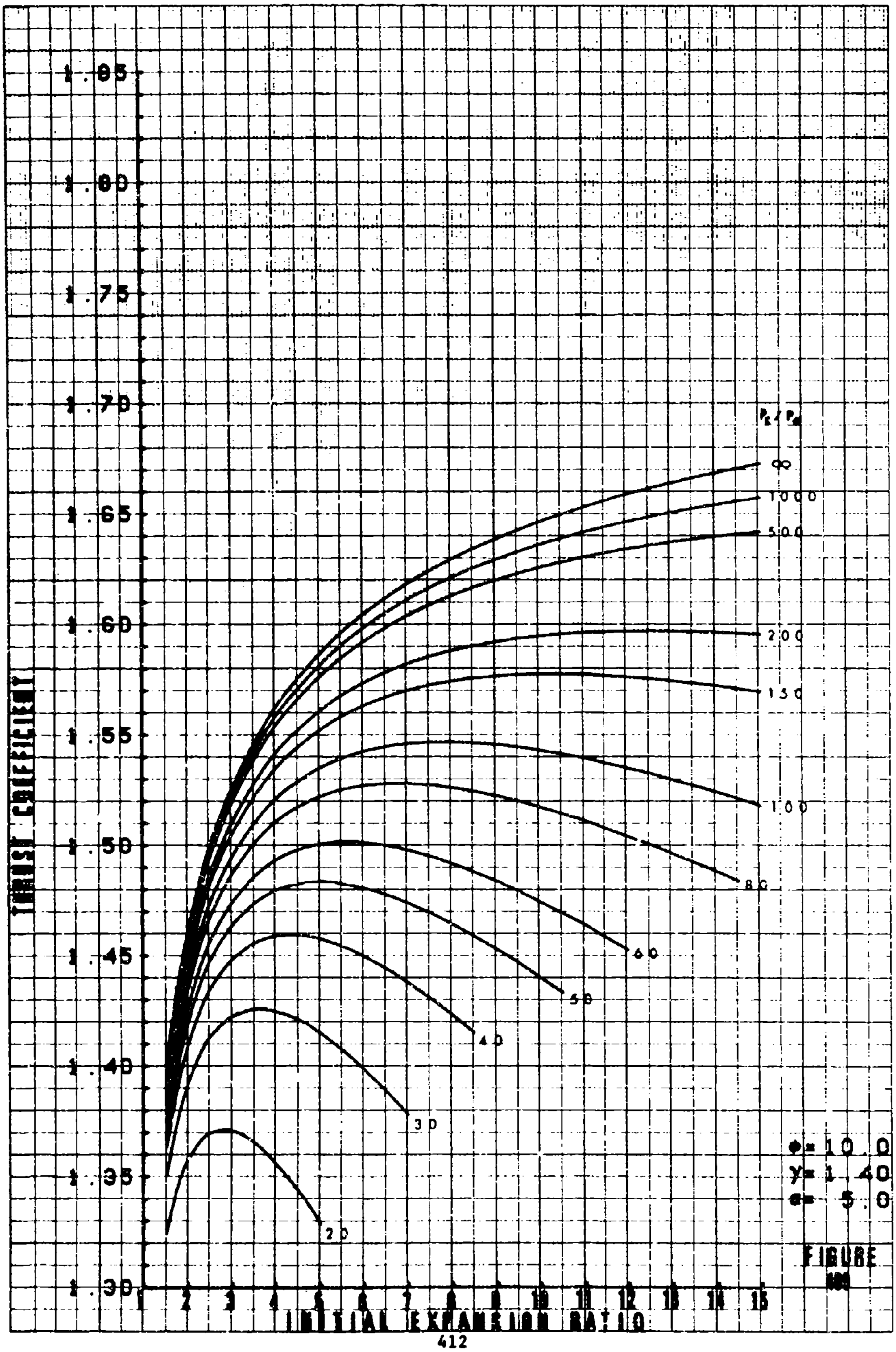
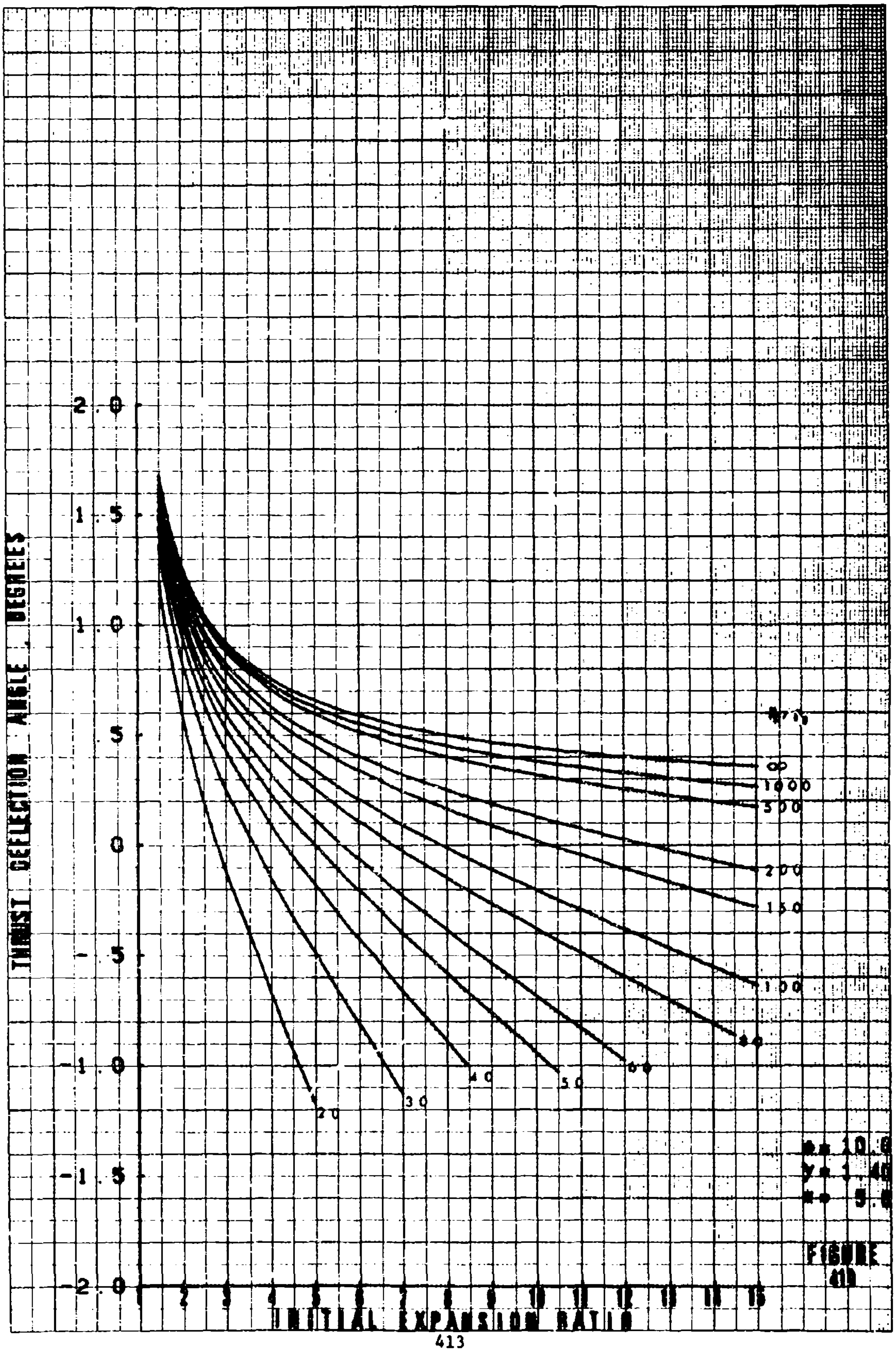

THRUST DEFLECTION ANGLE, IN DEGS
17.0
16.0
15.0
14.0
13.0
12.0
11.0
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
INITIAL EXPANSION RATIO
SCARF ANGLE
10
20
30
40
50
60
P_a = 0.0
γ = 1.40
ε = 5.0

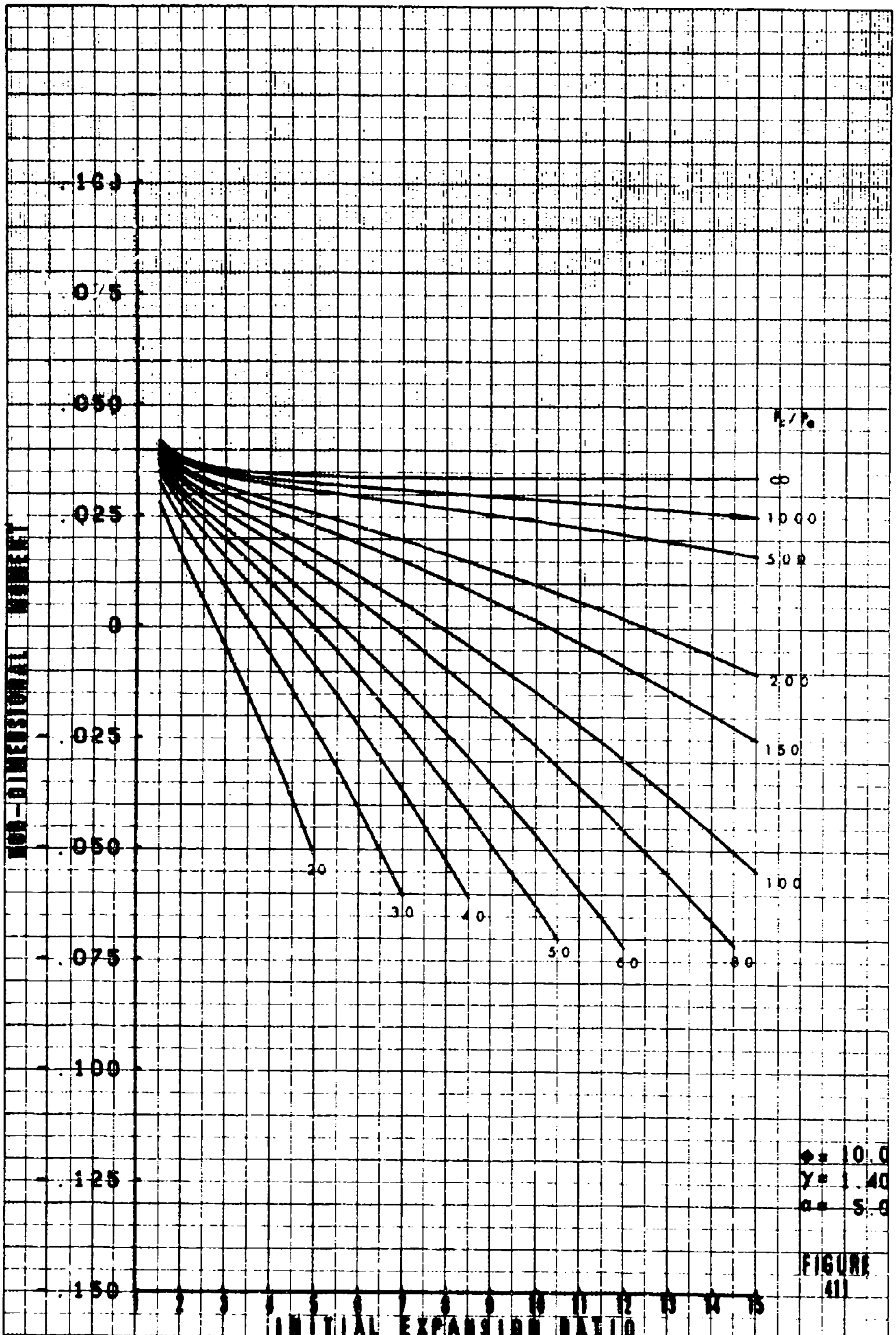
FIGURE 407

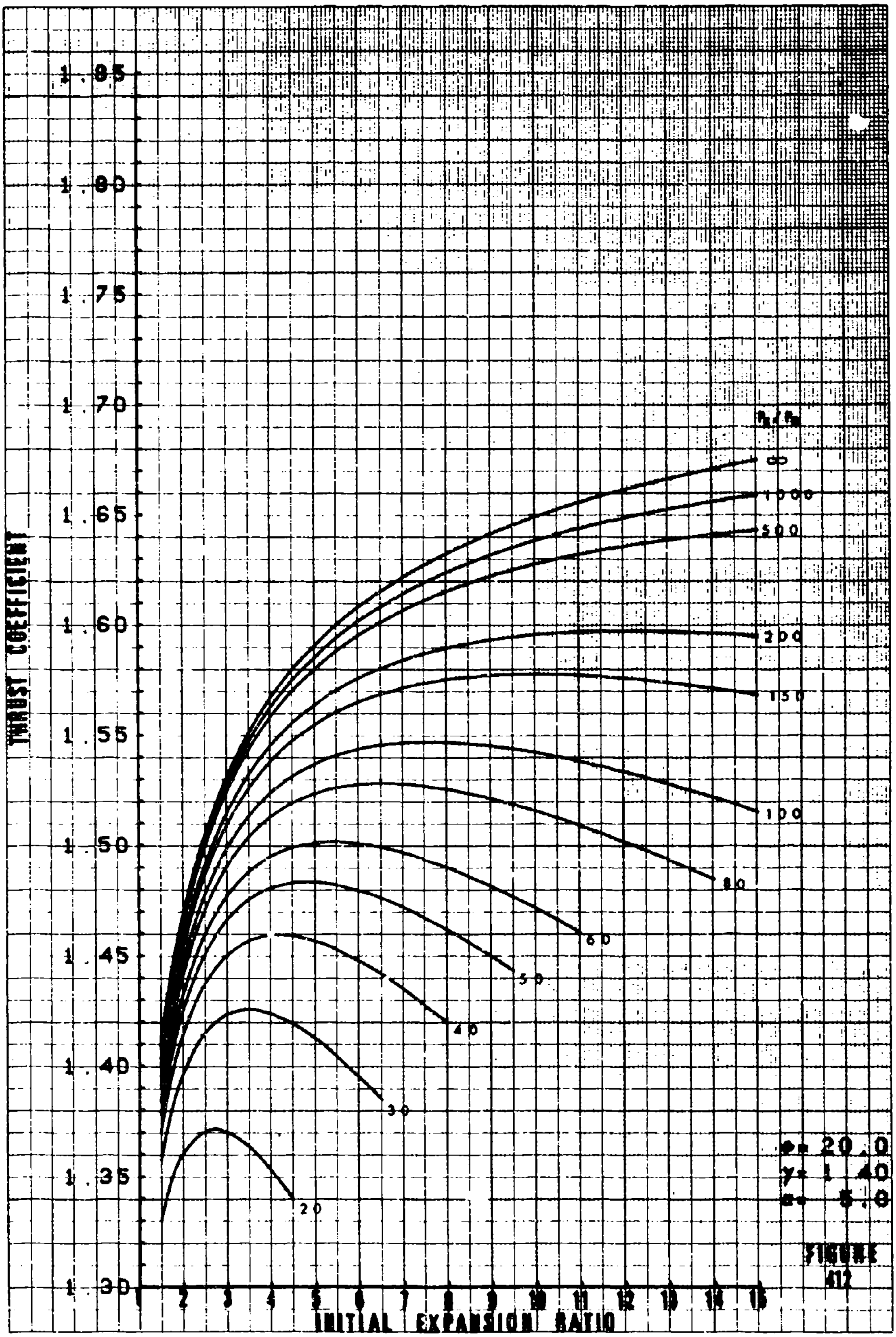

NON-DIMENSIONAL MOMENT
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
INITIAL EXPANSION RATIO
SCARF ANGLE
FIGURE

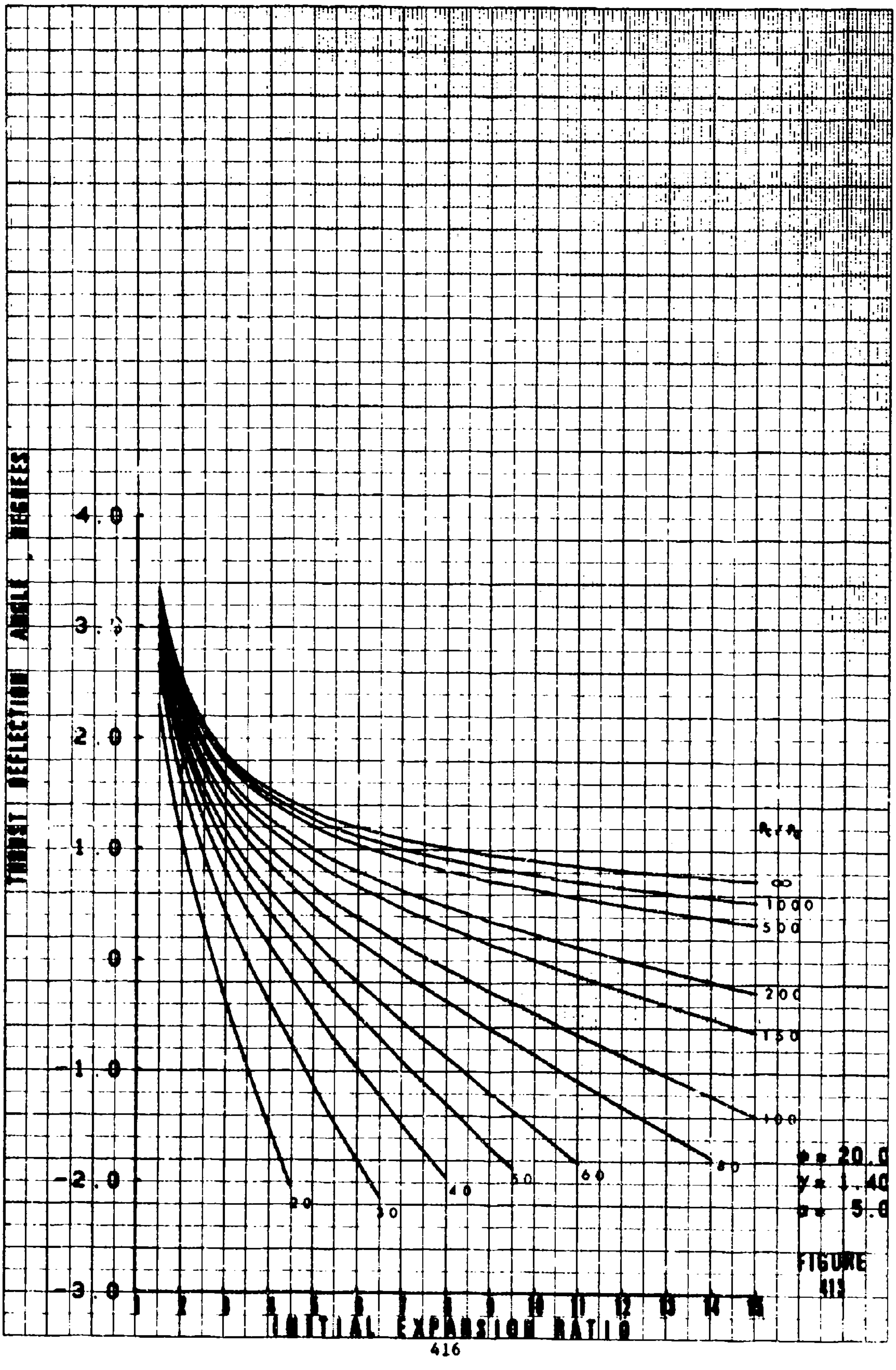

THRUST COEFFICIENT
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
INITIAL EXPANSION RATIO
P_c / P_a
∞
1000
500
200
150
100
80
60
50
40
30
20
ϕ= 10.0
γ= 1.40
α= 5.0
FIGURE

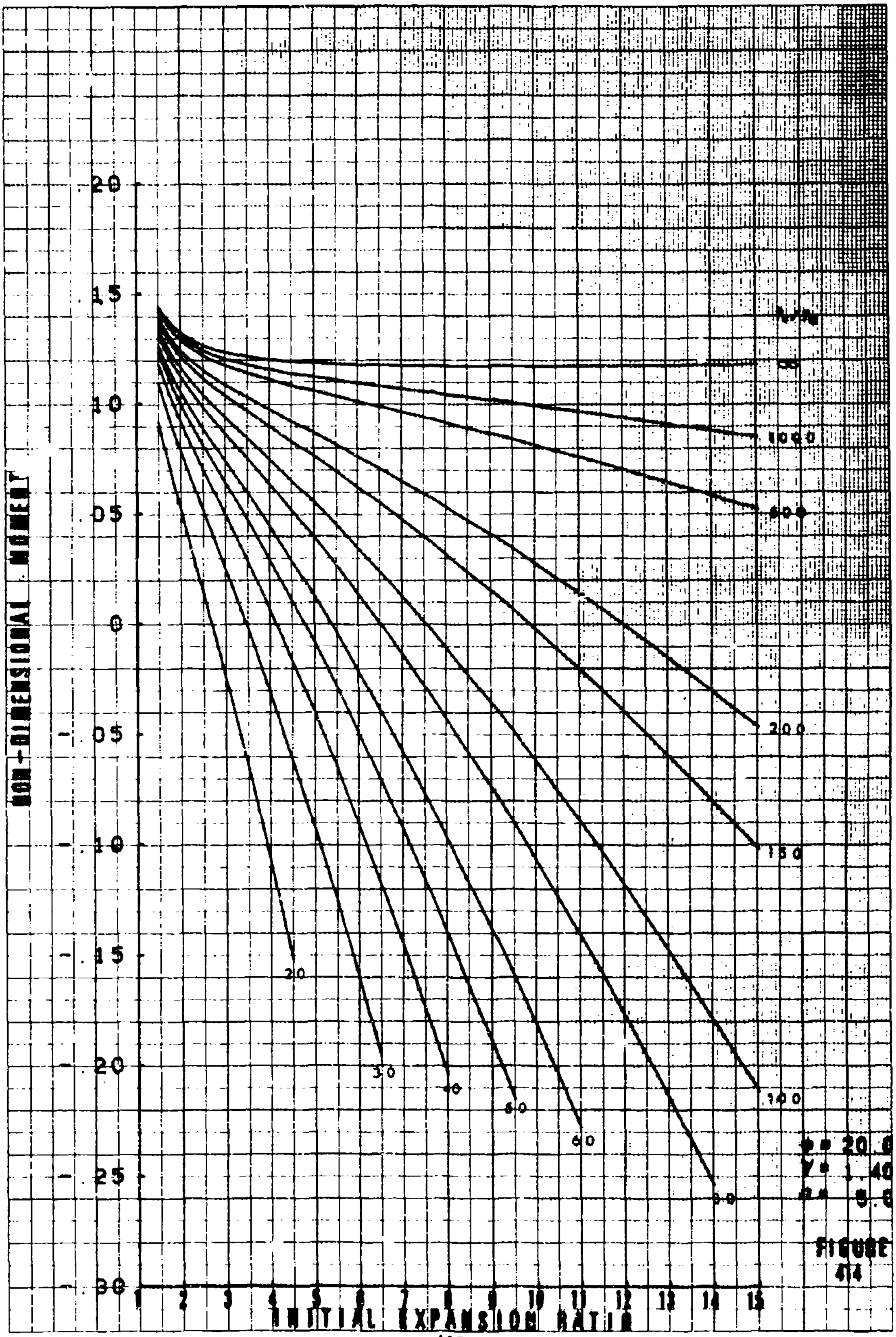


THRUST DEFLECTION ANGLE, DEGREES
INITIAL EXPANSION RATIO
2.0
1.5
1.0
.5
0
-.5
-1.0
-1.5
-2.0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
∞
1000
500
200
150
100
80
60
50
40
30
20
FIGURE

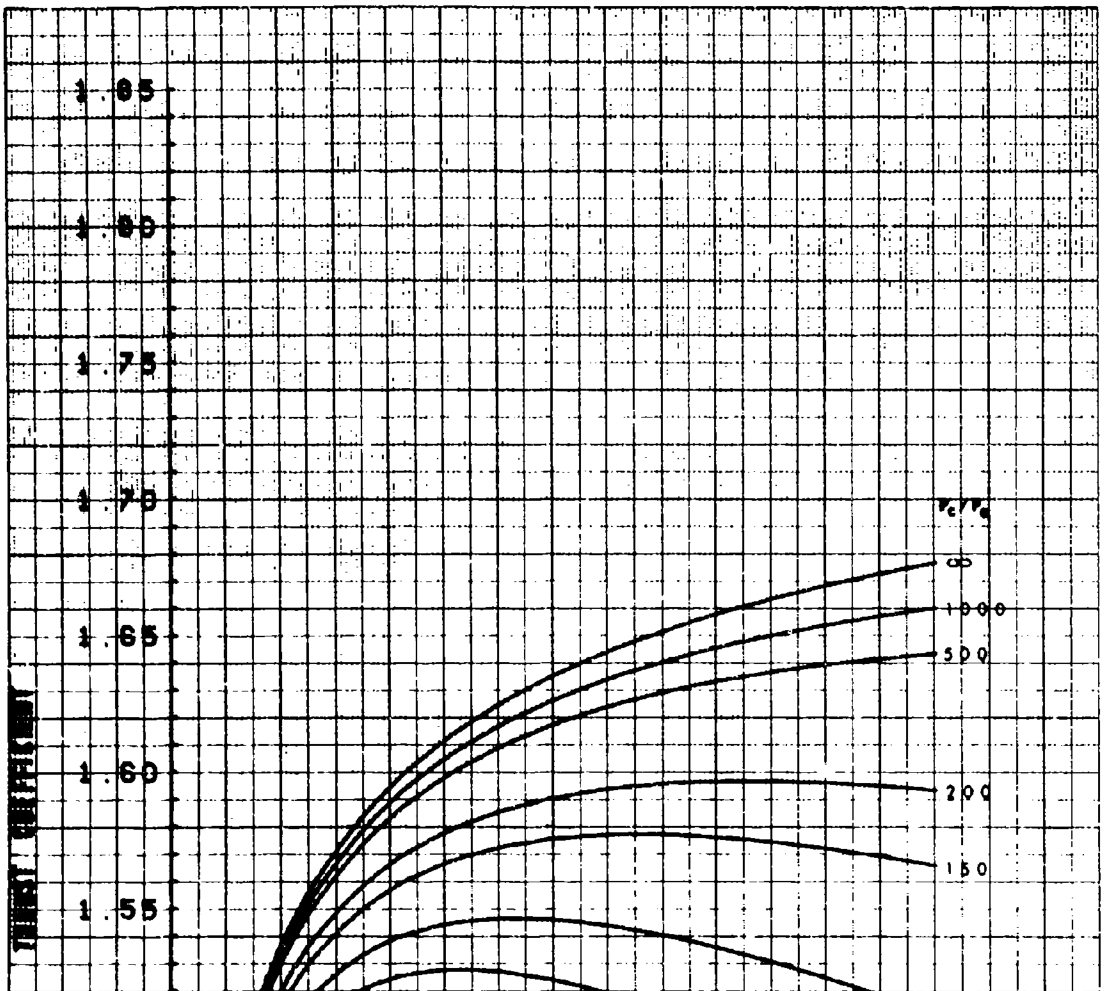

NON-DIMENSIONAL MOMENT
INITIAL EXPANSION RATIO
P_c/P_e
∞
1000
500
200
150
100
80
60
50
40
30
20
φ = 10.0
γ = 1.40
α = 5.0
FIGURE 411

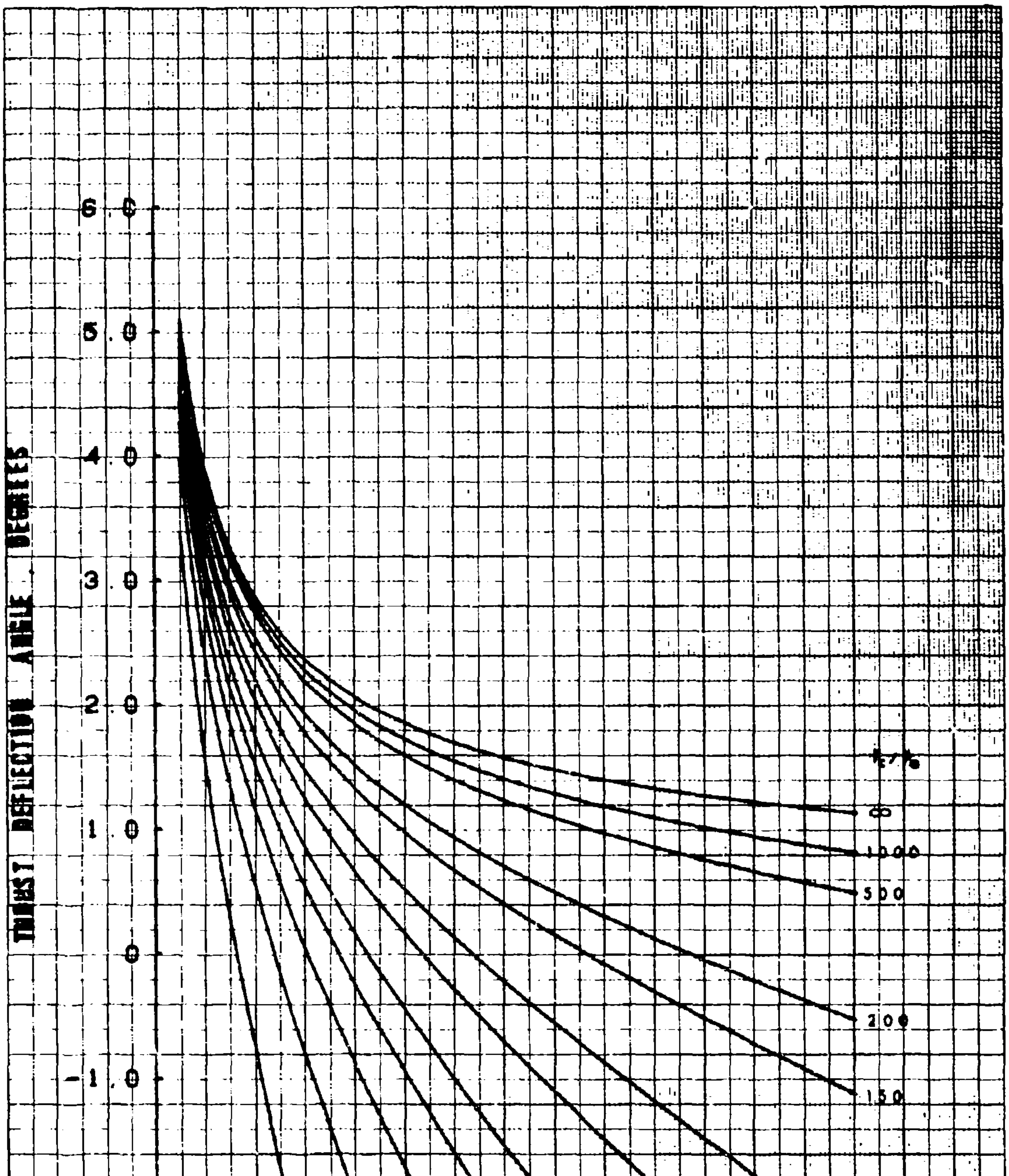

THRUST COEFFICIENT
INITIAL EXPANSION RATIO
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
∞
1000
500
200
150
100
80
60
50
40
30
20
ϕ = 20.0
γ = 1.40
FIGURE
412

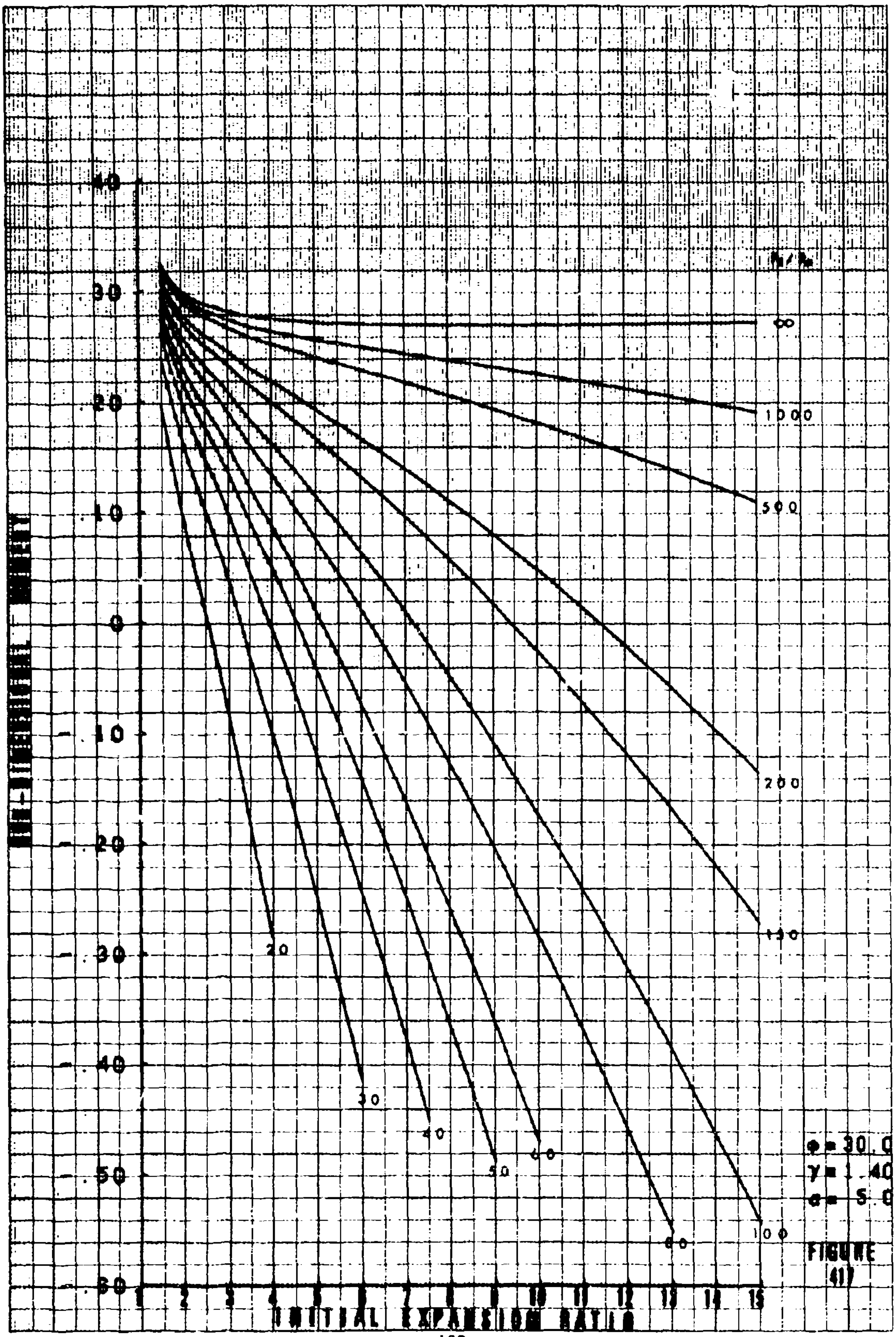

THRUST DEFLECTION ANGLE, DEGREES
INITIAL EXPANSION RATIO
P_c/P_a
∞
1000
500
200
150
100
80
60
50
40
30
20
FIGURE 413



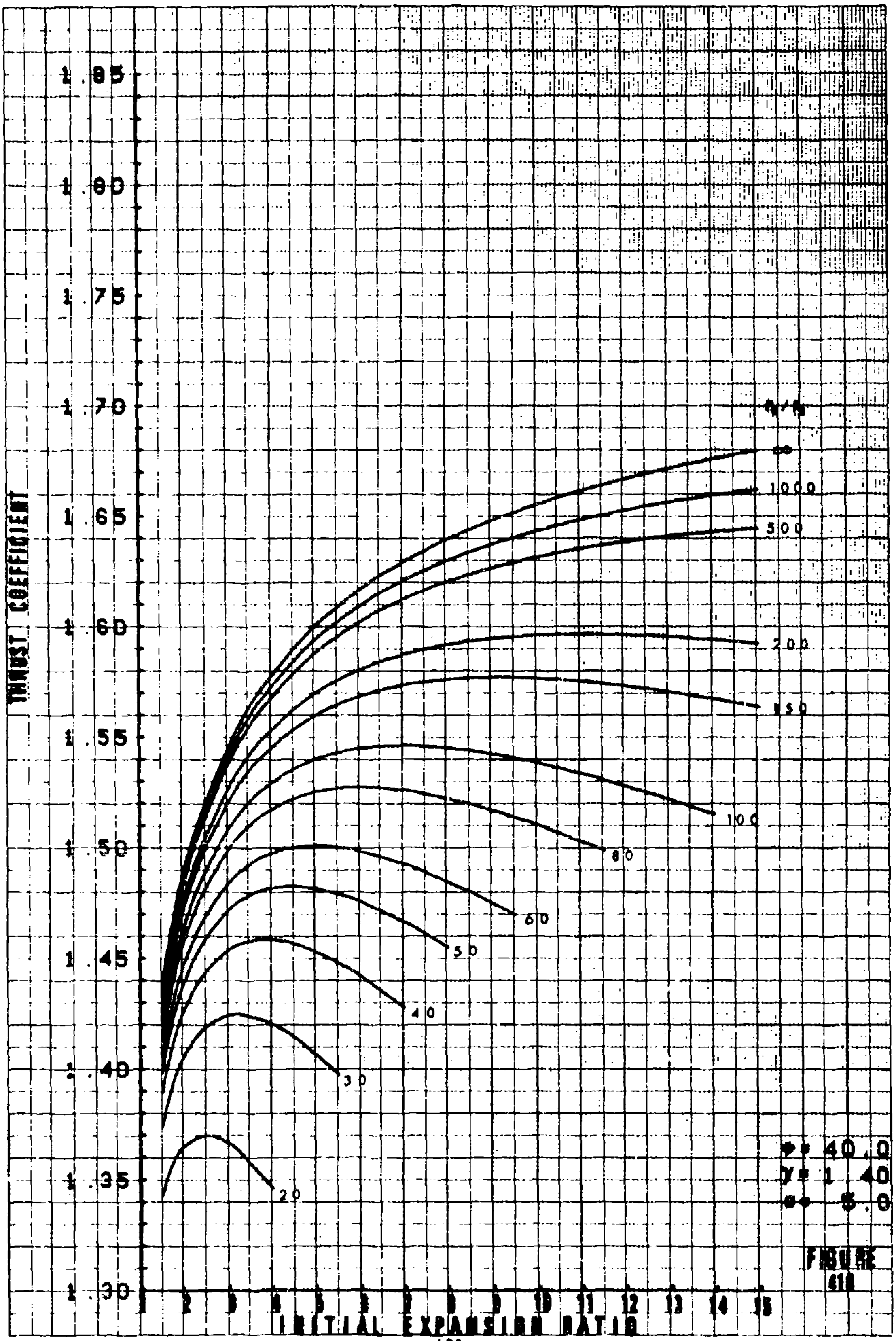
NON-DIMENSIONAL MOMENT
INITIAL EXPANSION RATIO
.20
.15
.10
.05
0
-.05
-.10
-.15
-.20
-.25
-.30
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
1000
600
200
150
100
20
30
40
50
60
80
FIGURE
414


THRUST COEFFICIENT
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
Pc/Pe
∞
1000
500
200
150
100
80
60
50
40
30
20
φ = 30.0
γ = 1.40
ε = 5.0
FIGURE 415


THRUST DEFLECTION ANGLE, DEGREES
6.0
5.0
4.0
3.0
2.0
1.0
0
-1.0
-2.0
-3.0
-4.0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
∞
1000
500
200
150
100
80
60
50
40
30
20
FIGURE



40
30
20
10
0
-10
-20
-30
-40
-50
-60
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
∞
1000
500
200
150
100
80
60
50
40
30
20
φ = 30.0
γ = 1.40
α = 5.0
FIGURE


1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
THRUST COEFFICIENT
INITIAL EXPANSION RATIO
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
1000
500
200
150
100
80
60
50
40
30
20
40.0
1.40
5.0
FIGURE

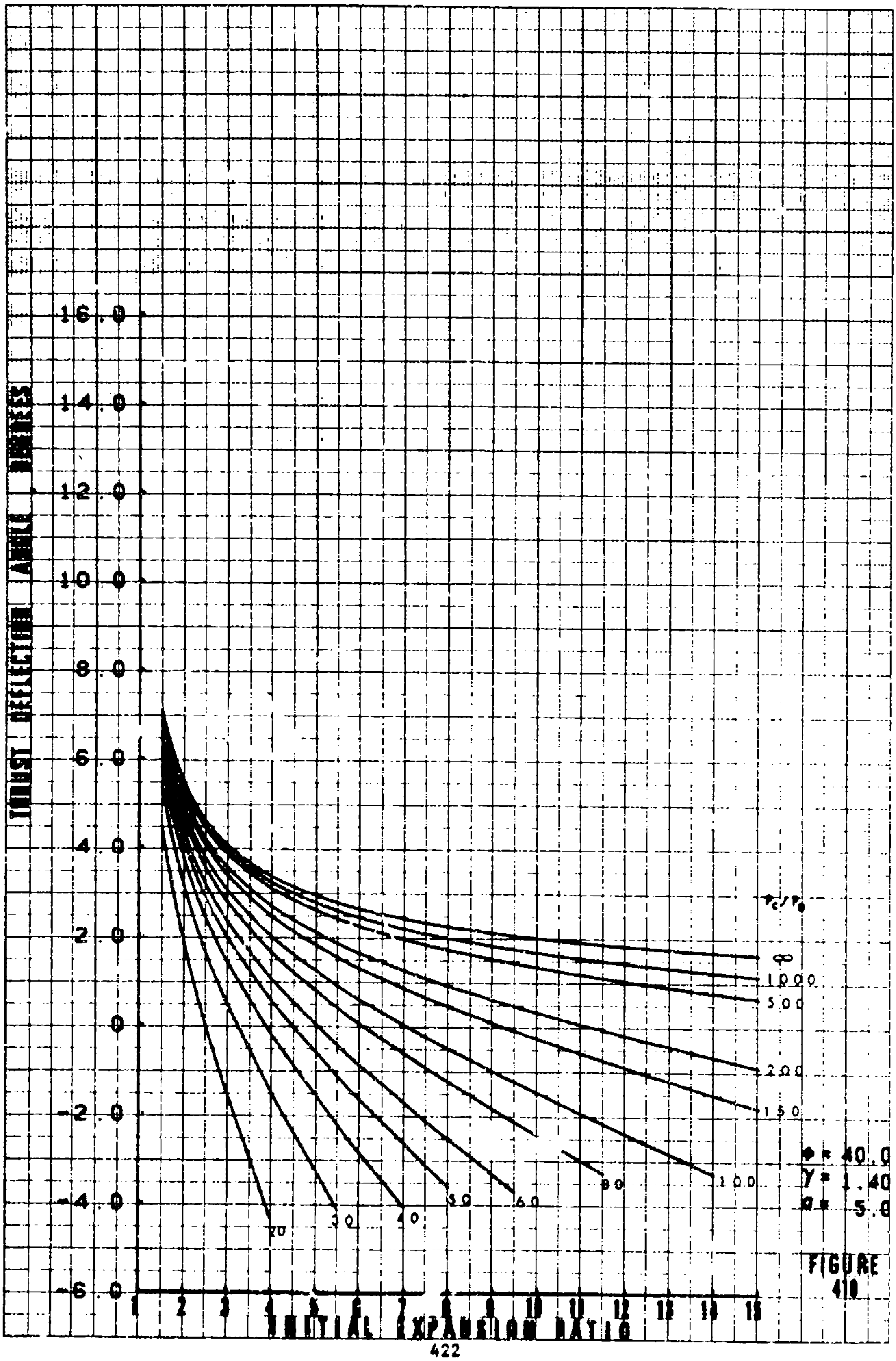
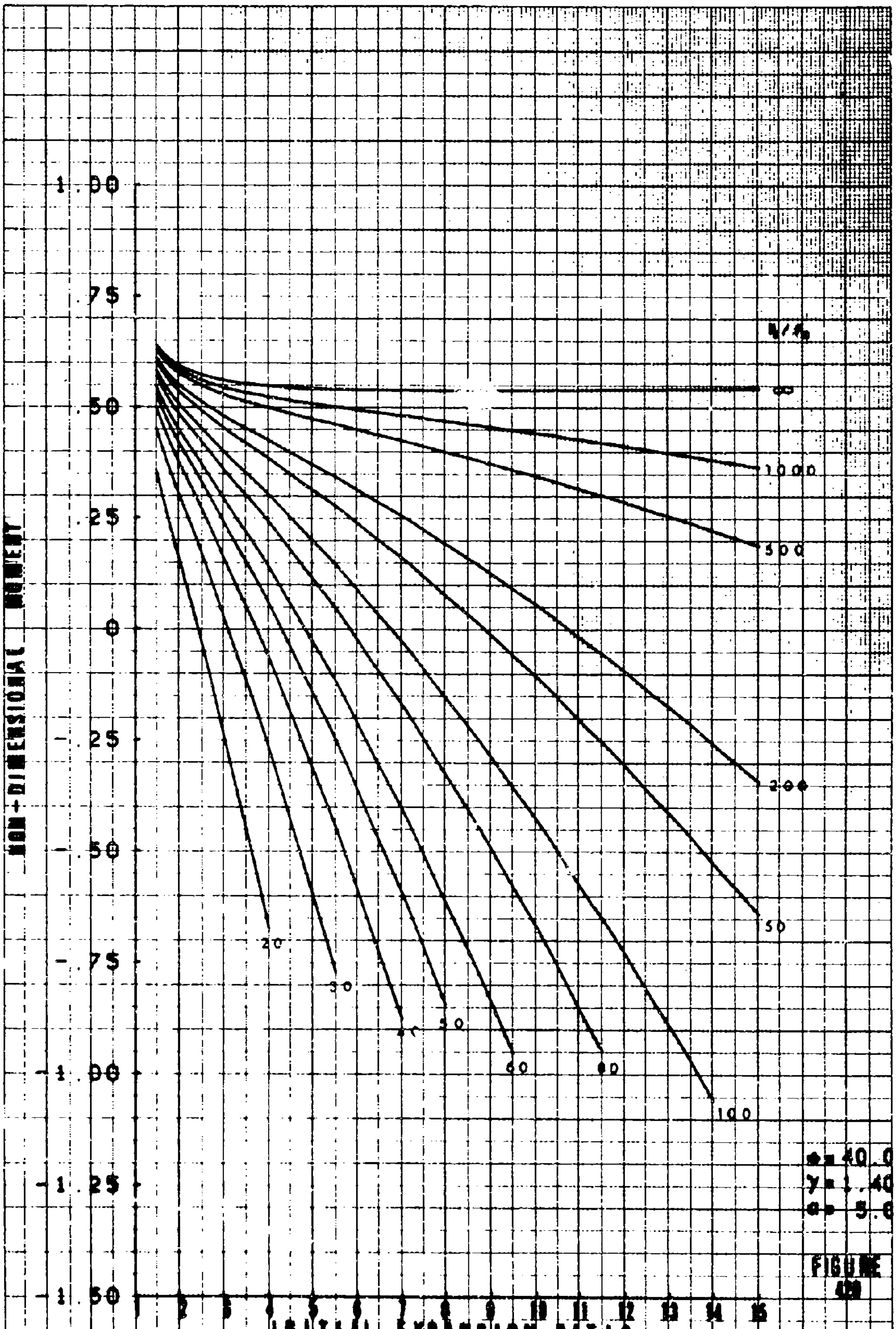

THRUST DEFLECTION ANGLE DEGREES
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0
-2.0
-4.0
-6.0
P_c/P_a
∞
1000
500
200
150
100
80
60
50
40
30
20
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
INITIAL EXPANSION RATIO
ϕ = 40.0
γ = 1.40
5.0

FIGURE 410



1.00
.75
.50
.25
0
-.25
-.50
-.75
-1.00
-1.25
-1.50
NON-DIMENSIONAL MOMENT
INITIAL EXPANSION RATIO
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
1000
500
200
50
20
30
40
50
60
80
100

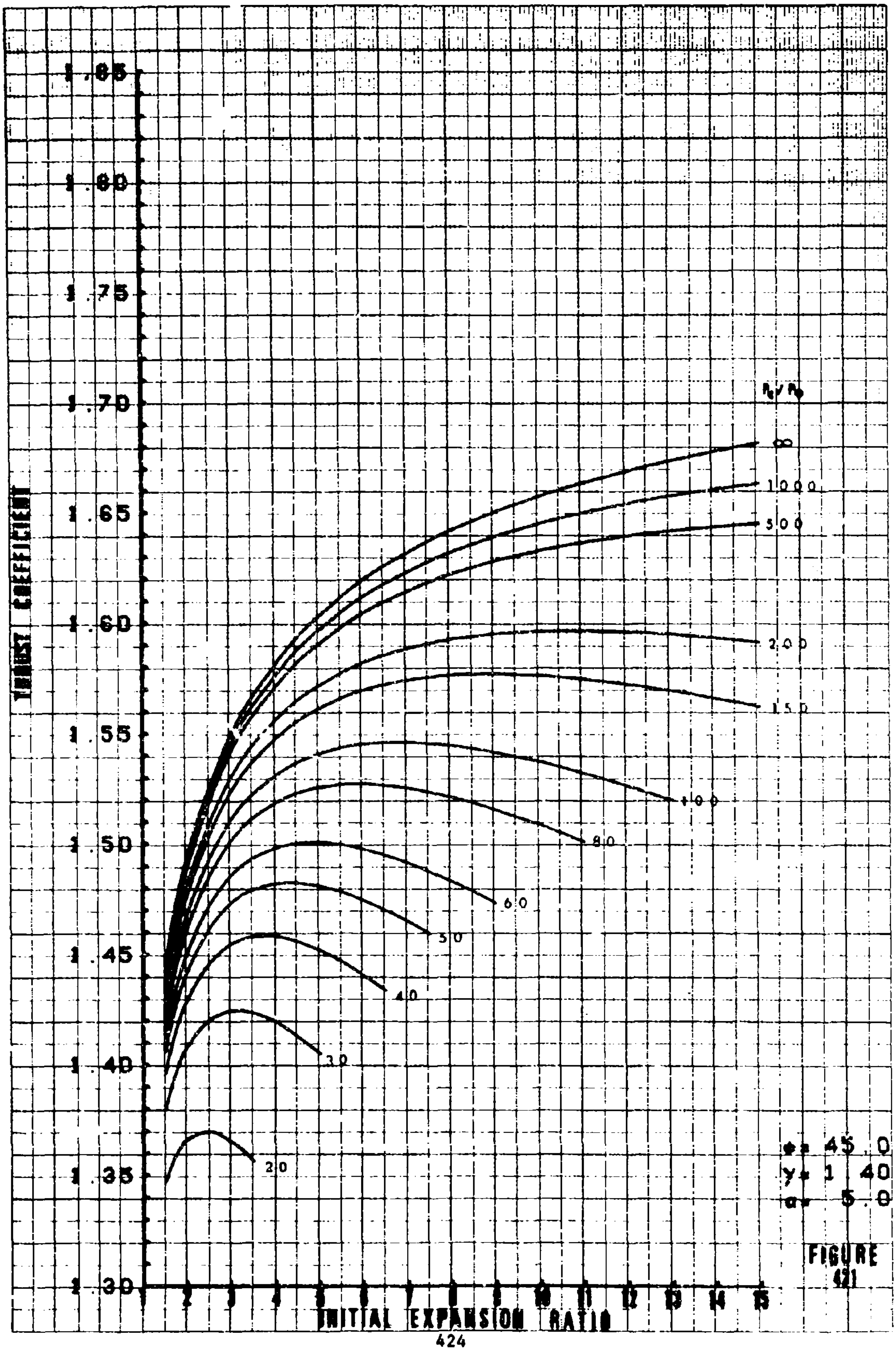
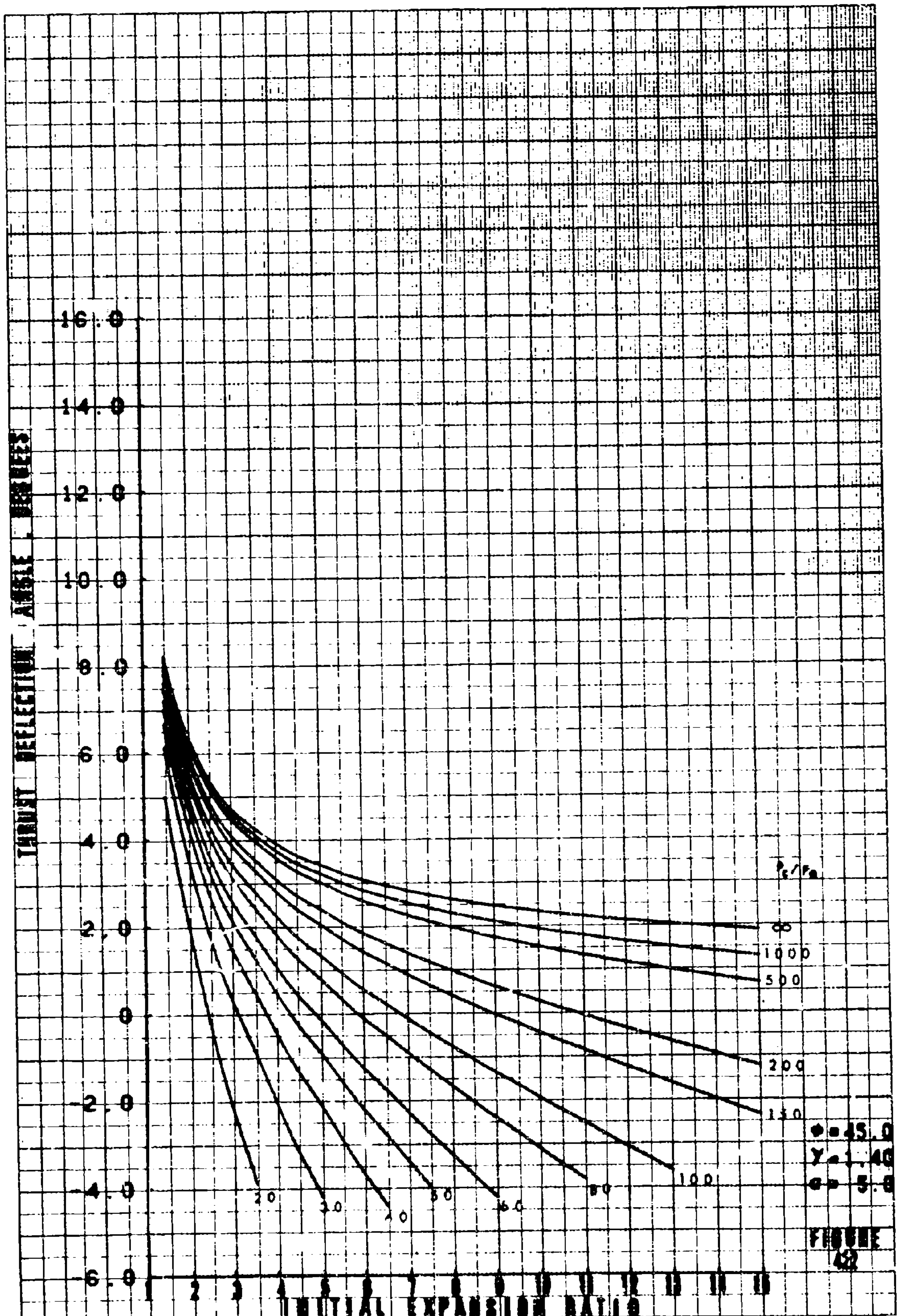
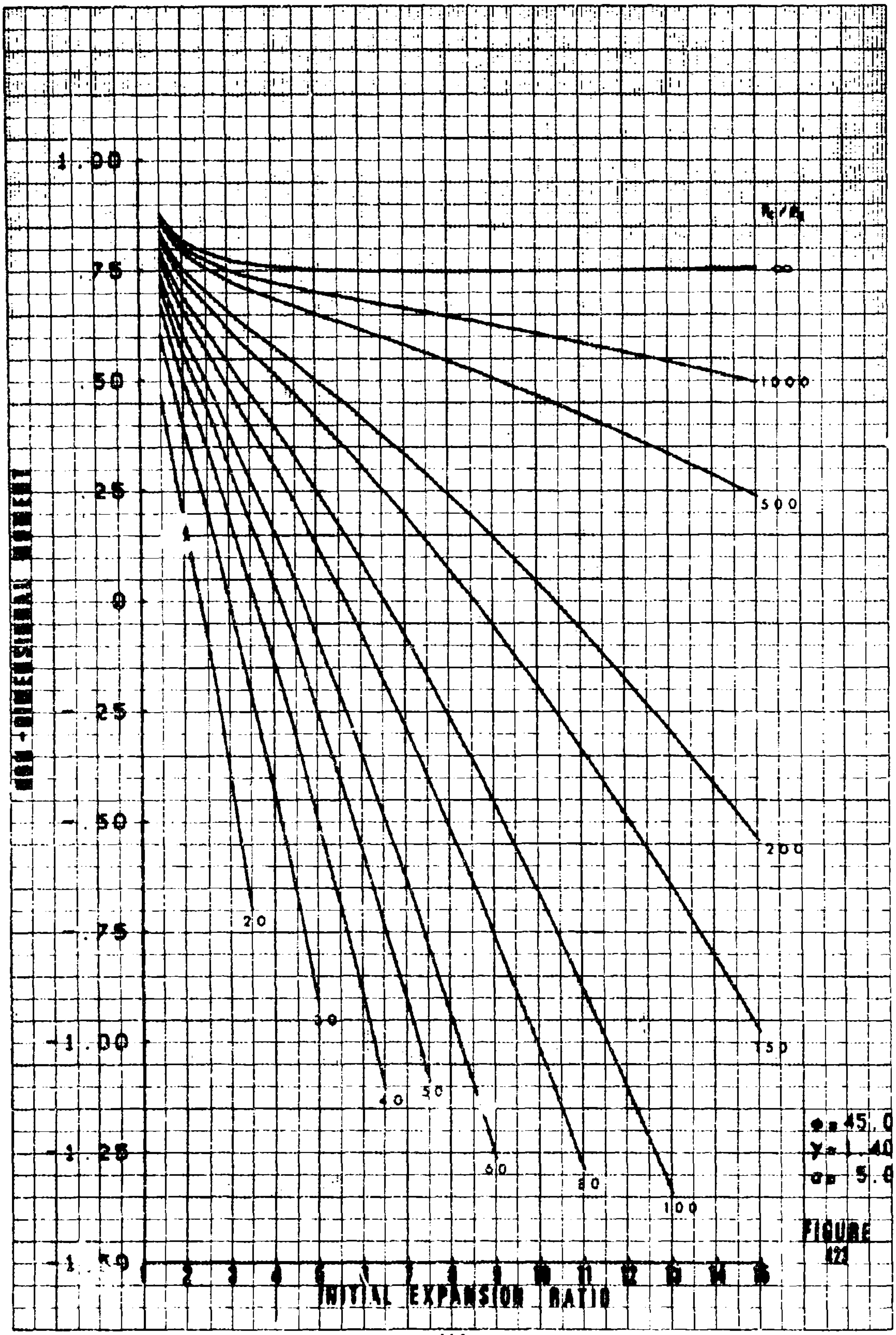

1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
THRUST COEFFICIENT
P_c/P_b
∞
1000
500
200
150
100
80
60
50
40
30
20
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
φ= 45.0
γ= 1.40
α= 5.0

FIGURE 421


THRUST DEFLECTION ANGLE, DEGREES
INITIAL EXPANSION RATIO
P_c/P_a
∞
1000
500
200
150
100
80
60
50
40
30
20
φ = 45.0
γ = 1.40
σ = 5.8
FIGURE 42



1.00
.75
.50
.25
0
-.25
-.50
-.75
-1.00
-1.25
-1.50
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
INITIAL EXPANSION RATIO
NON-DIMENSIONAL MOMENT
∞
1000
500
200
150
100
80
60
50
40
30
20
φ = 45.0
γ = 1.40
σ = 5.0

FIGURE 423

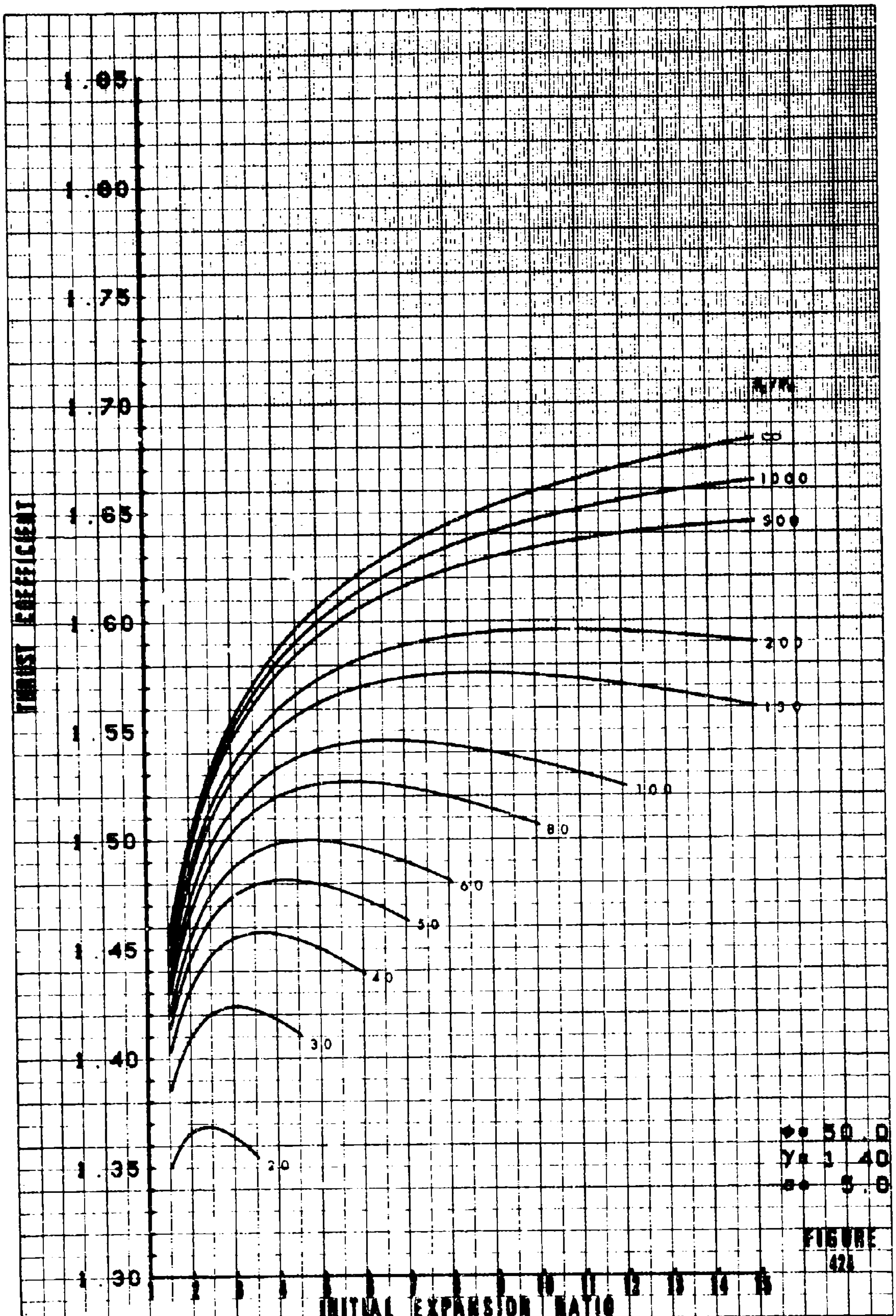
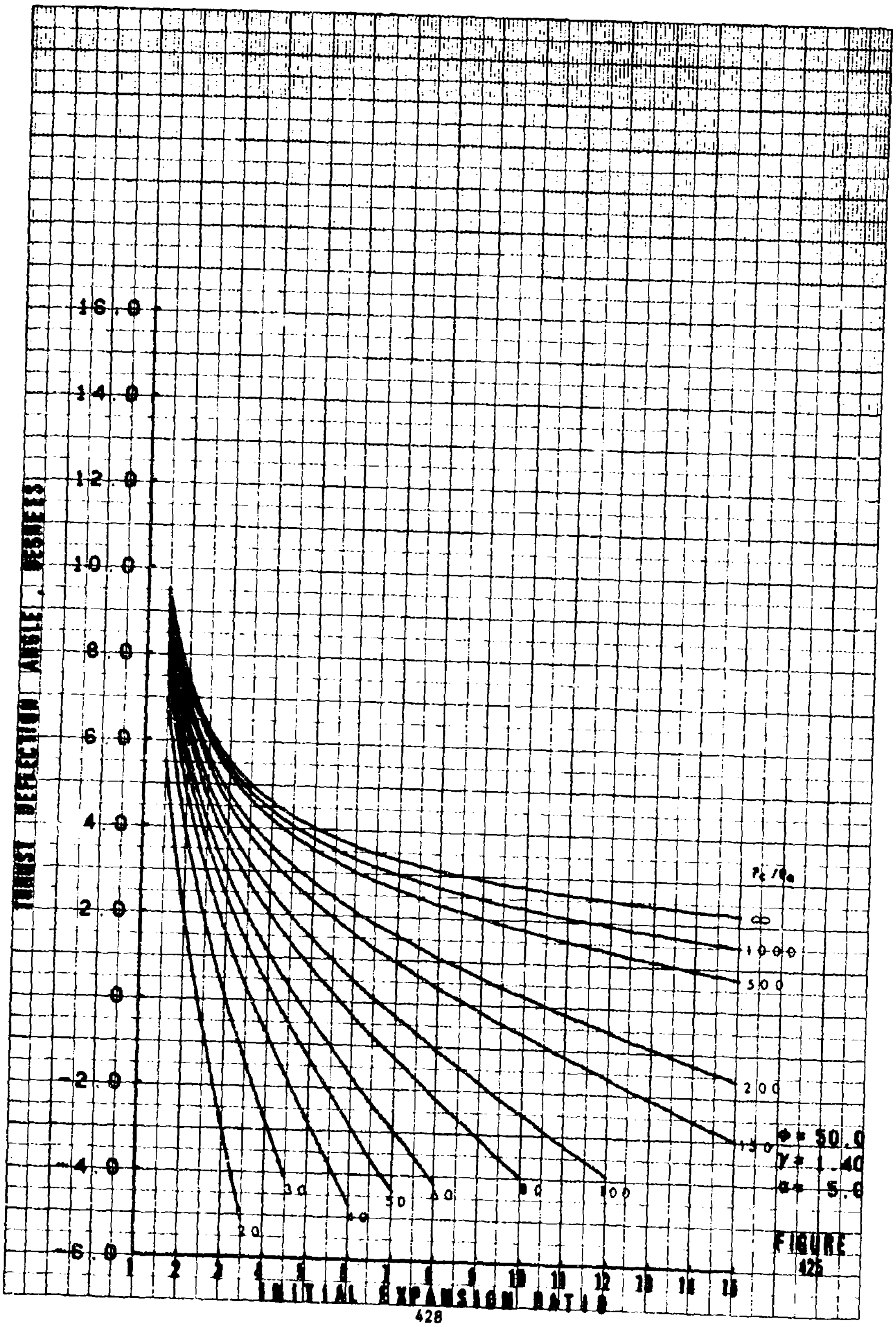
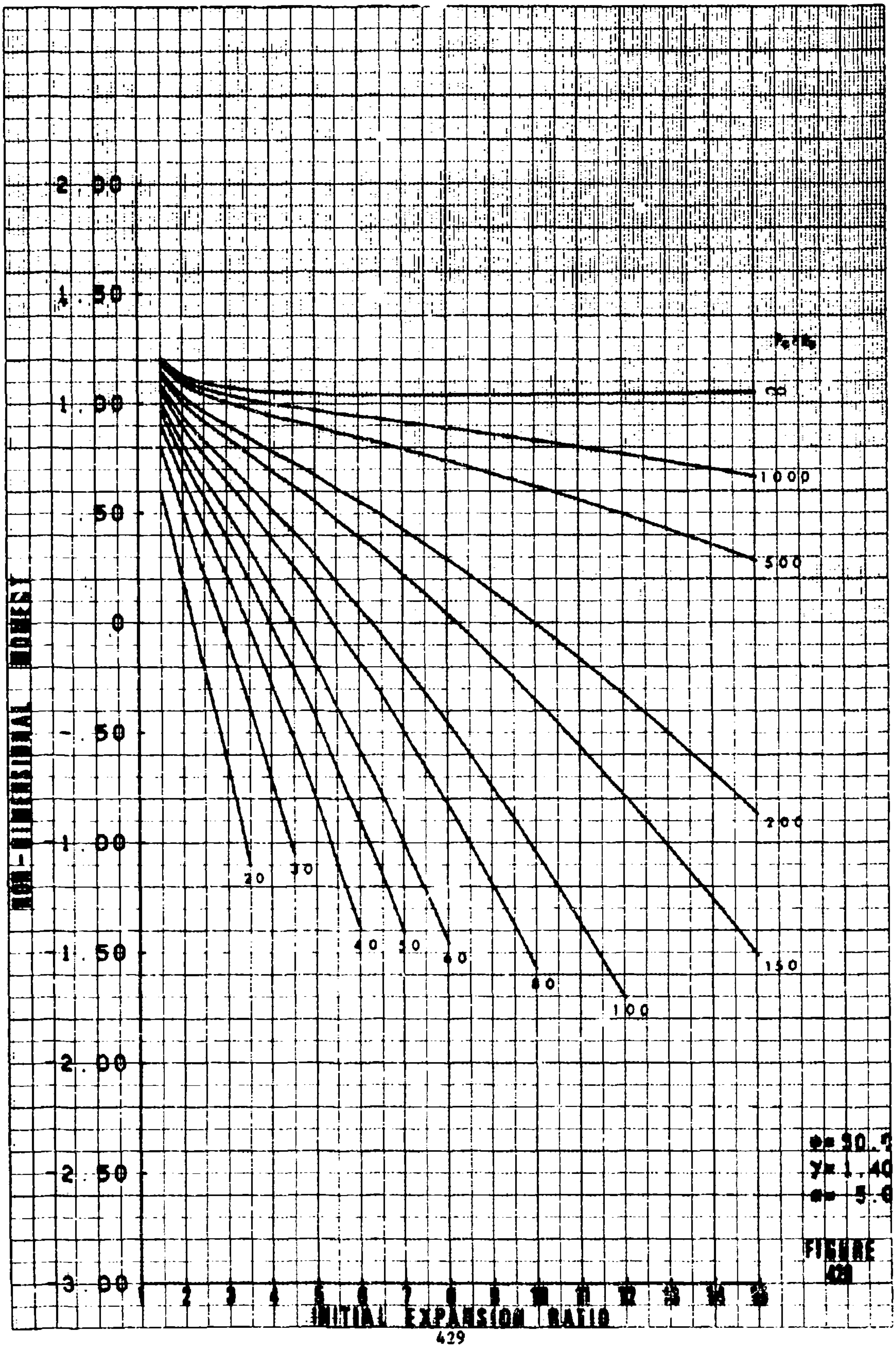

THRUST COEFFICIENT
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
INITIAL EXPANSION RATIO
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
∞
1000
500
200
150
100
80
60
50
40
30
20

FIGURE 42



THRUST DEFLECTION ANGLE, DEGREES
INITIAL EXPANSION RATIO
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0
-2.0
-4.0
-6.0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
P_c/P_a
∞
1000
500
200
150
100
80
60
50
40
30
20
Φ = 50.0
γ = 1.40
α = 5.0
FIGURE 425


2.00
1.50
1.00
.50
0
-.50
-1.00
-1.50
-2.00
-2.50
-3.00
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
INITIAL EXPANSION RATIO
20
30
40
50
60
80
100
150
200
500
1000
∞
γ= 1.40
FIGURE

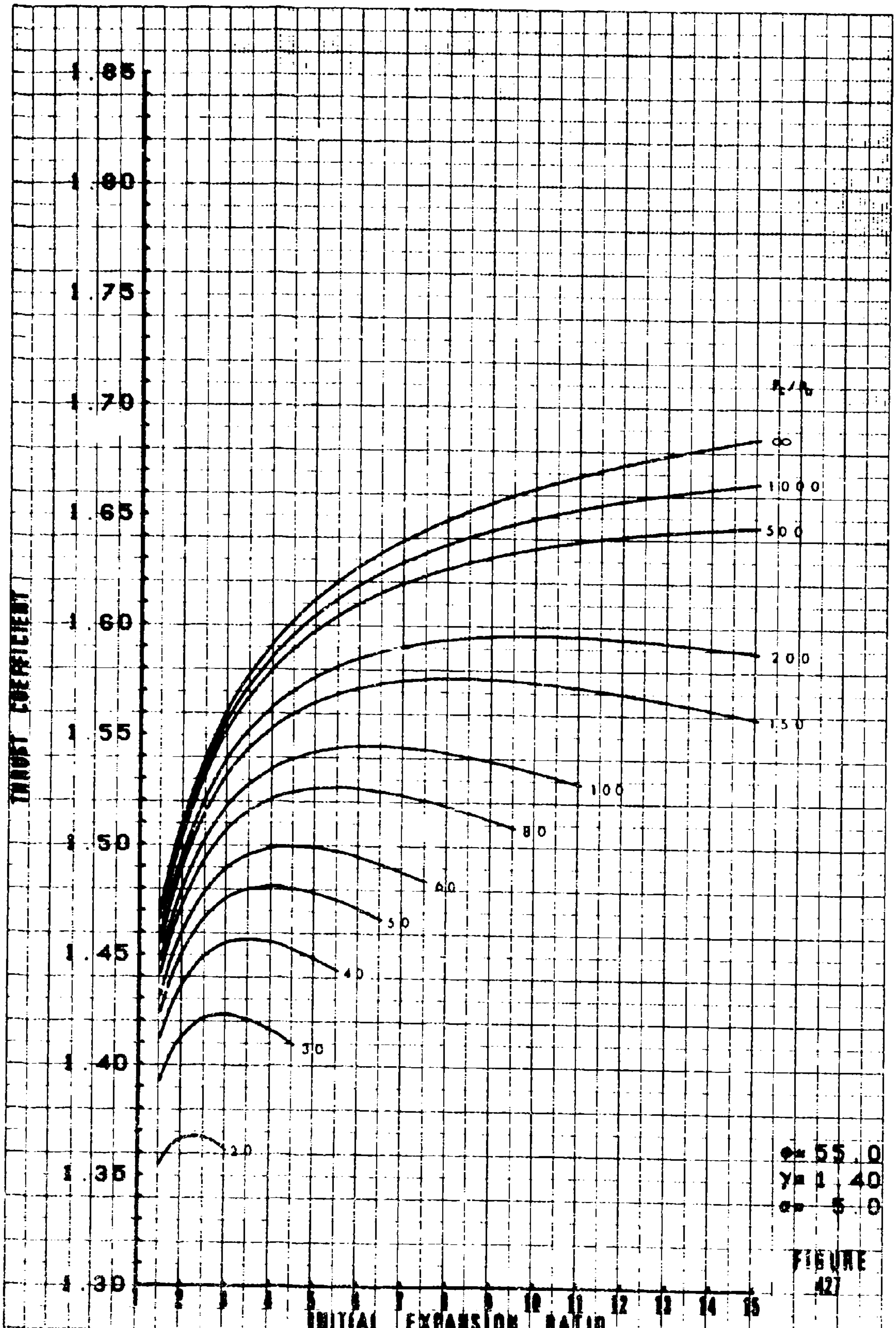
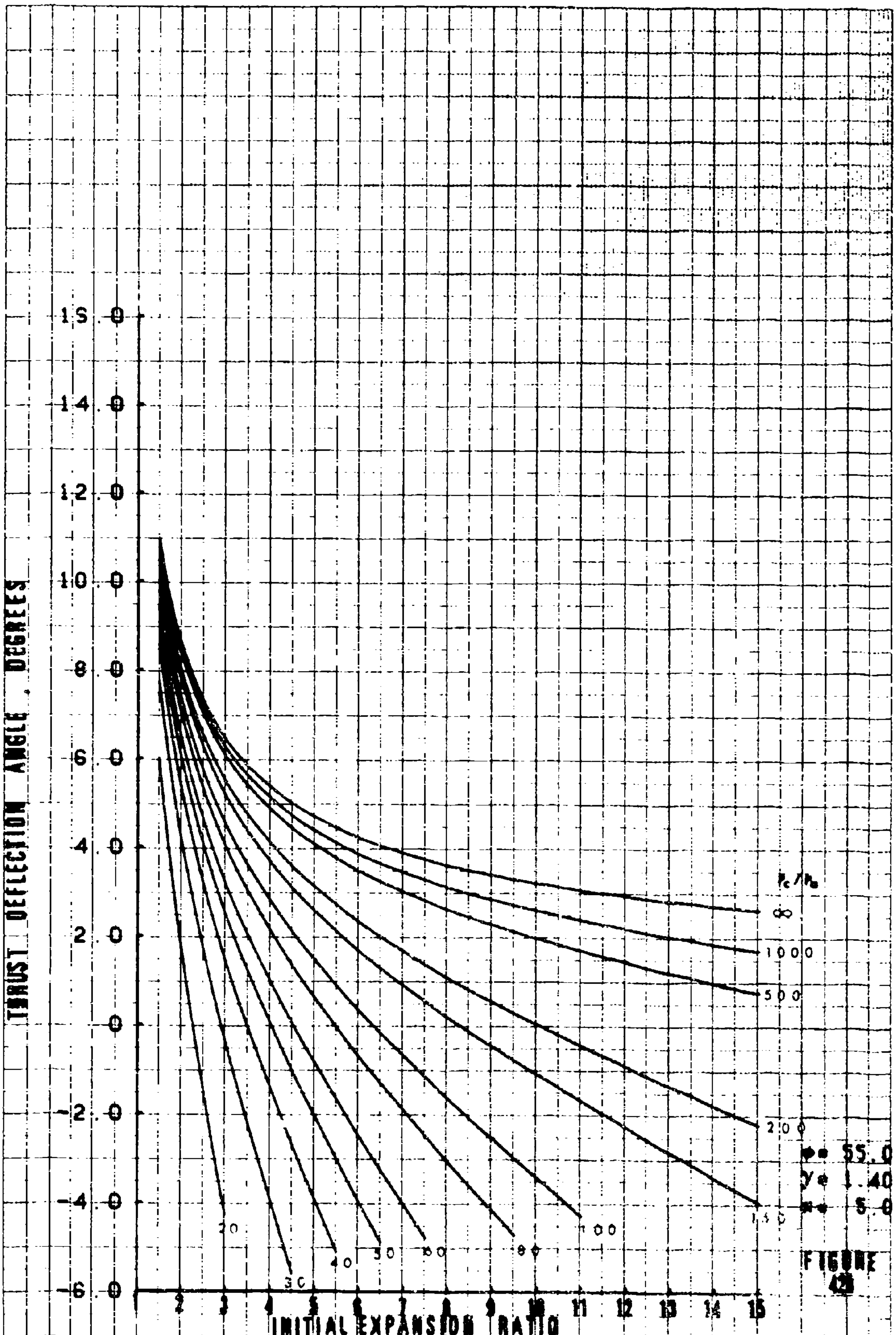
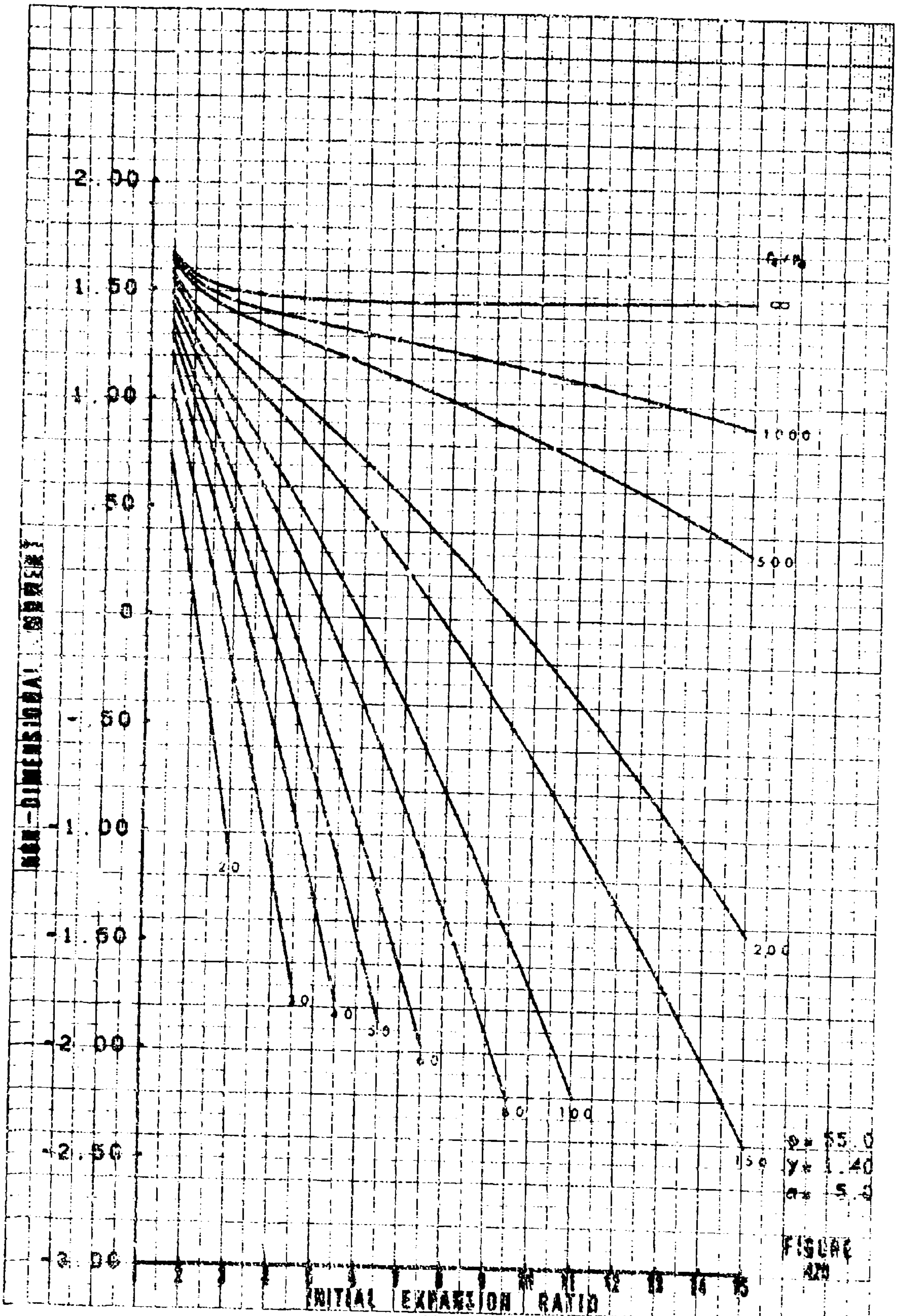

THRUST COEFFICIENT
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
INITIAL EXPANSION RATIO
P_c/P_a
∞
1000
500
200
150
100
80
60
50
40
30
20
Φ= 55.0
γ= 1.40
α= 5.0

FIGURE 427

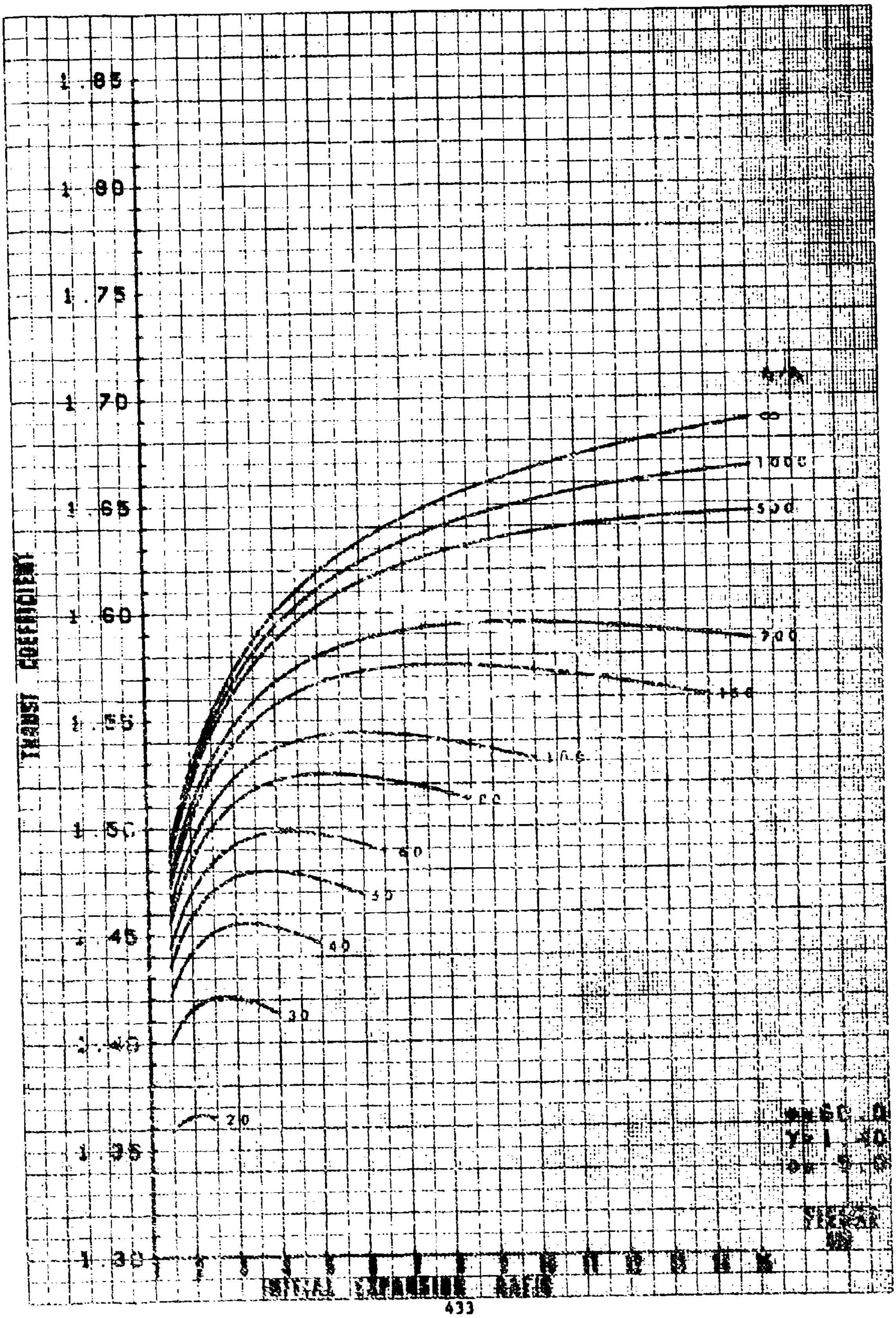


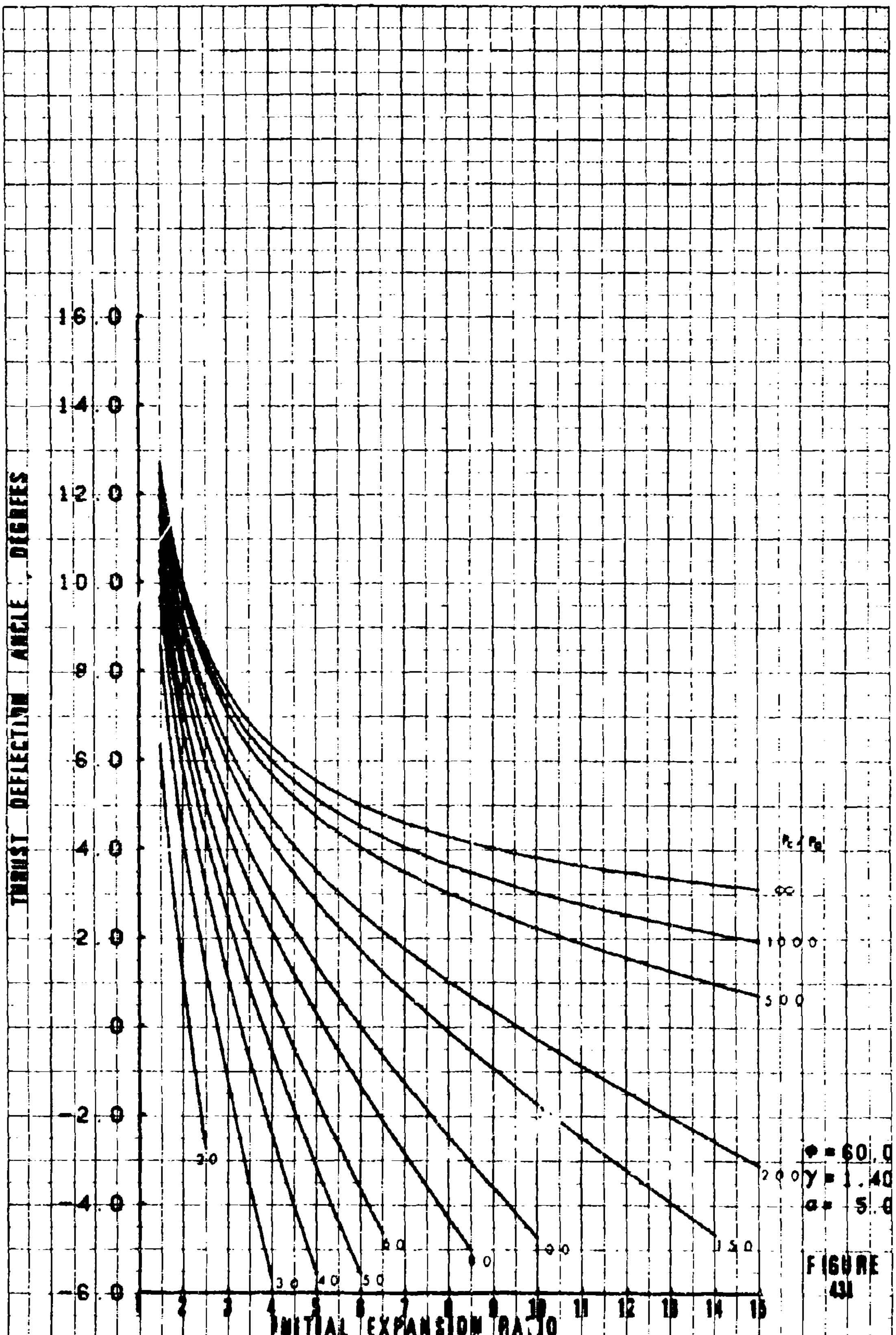
THRUST DEFLECTION ANGLE, DEGREES
INITIAL EXPANSION RATIO
P_c/P_a
∞
1000
500
200
150
100
80
60
50
40
30
20

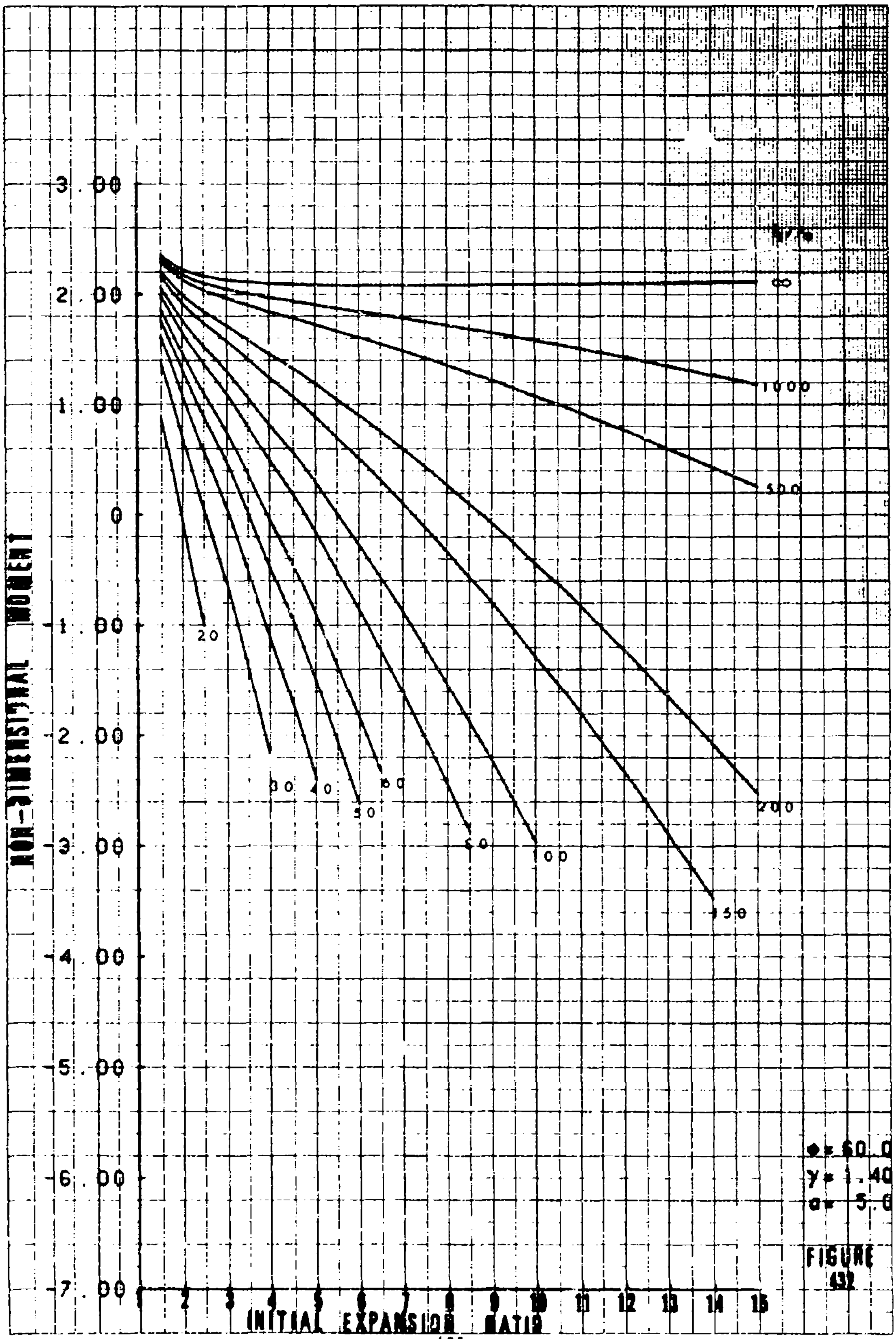
FIGURE 42



2.00
1.50
1.00
.50
0
-.50
-1.00
-1.50
-2.00
-2.50
-3.00
NON-DIMENSIONAL
∞
1000
500
200
150
100
80
60
50
40
30
20
φ = 55.0
γ = 1.40
α = 5.0
2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO

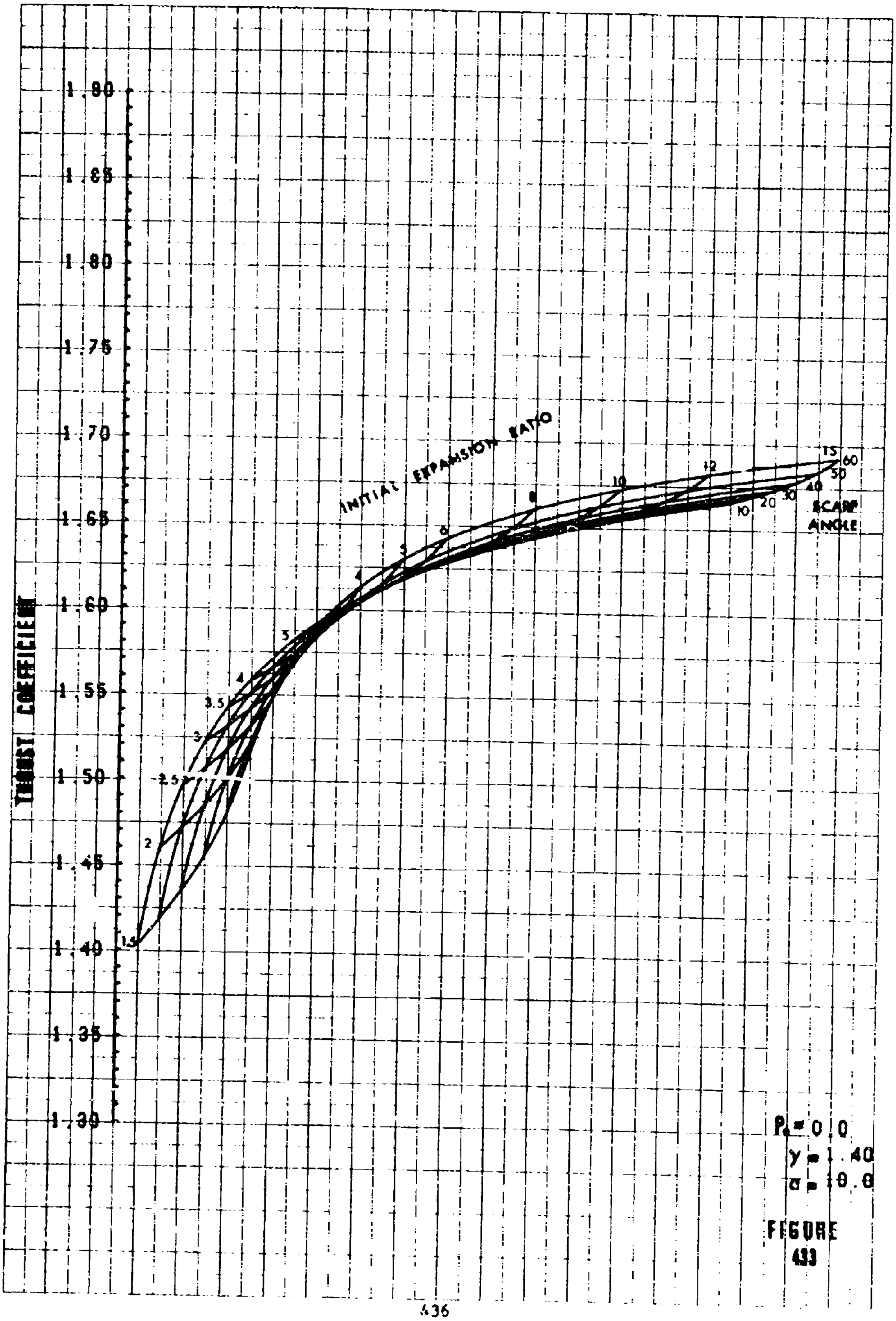

1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
THRUST COEFFICIENT
INITIAL EXPANSION RATIO
1000
500
200
150
100
80
60
50
40
30
20


THRUST DEFLECTION ANGLE , DEGREES
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0
-2.0
-4.0
-6.0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
INITIAL EXPANSION RATIO
P_c / P_a
∞
1000
500
200
150
100
80
60
50
40
30
20
Φ = 60.0
γ = 1.40
a = 5.0
FIGURE
431



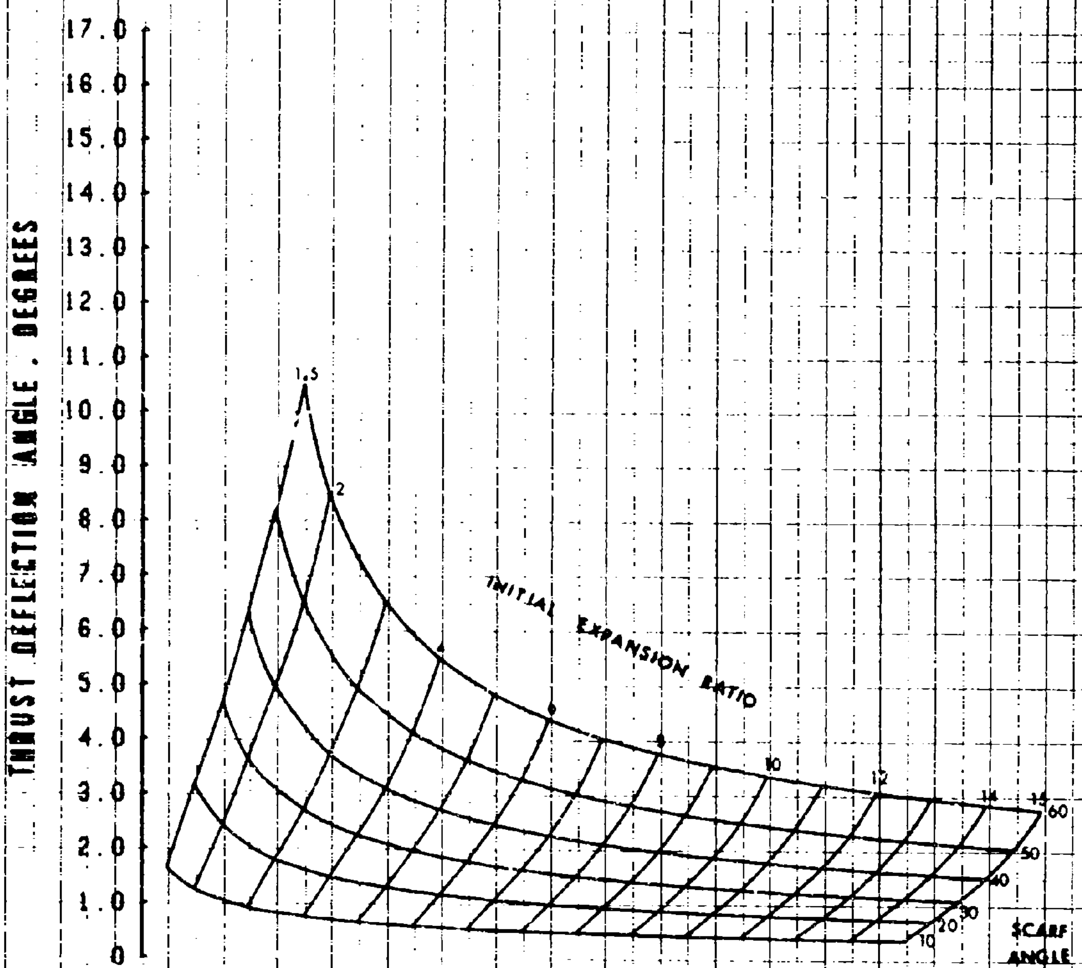
3.00
2.00
1.00
0
-1.00
-2.00
-3.00
-4.00
-5.00
-6.00
-7.00
NON-DIMENSIONAL MOMENT
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
∞
1000
500
200
150
100
80
60
50
40
30
20

FIGURE 432



$P_a = 0.0$
$\gamma = 1.40$
$\alpha = 0.0$

FIGURE 433



$P_a = 0.0$
$\gamma = 1.40$
$\theta = 10.0$

FIGURE 434

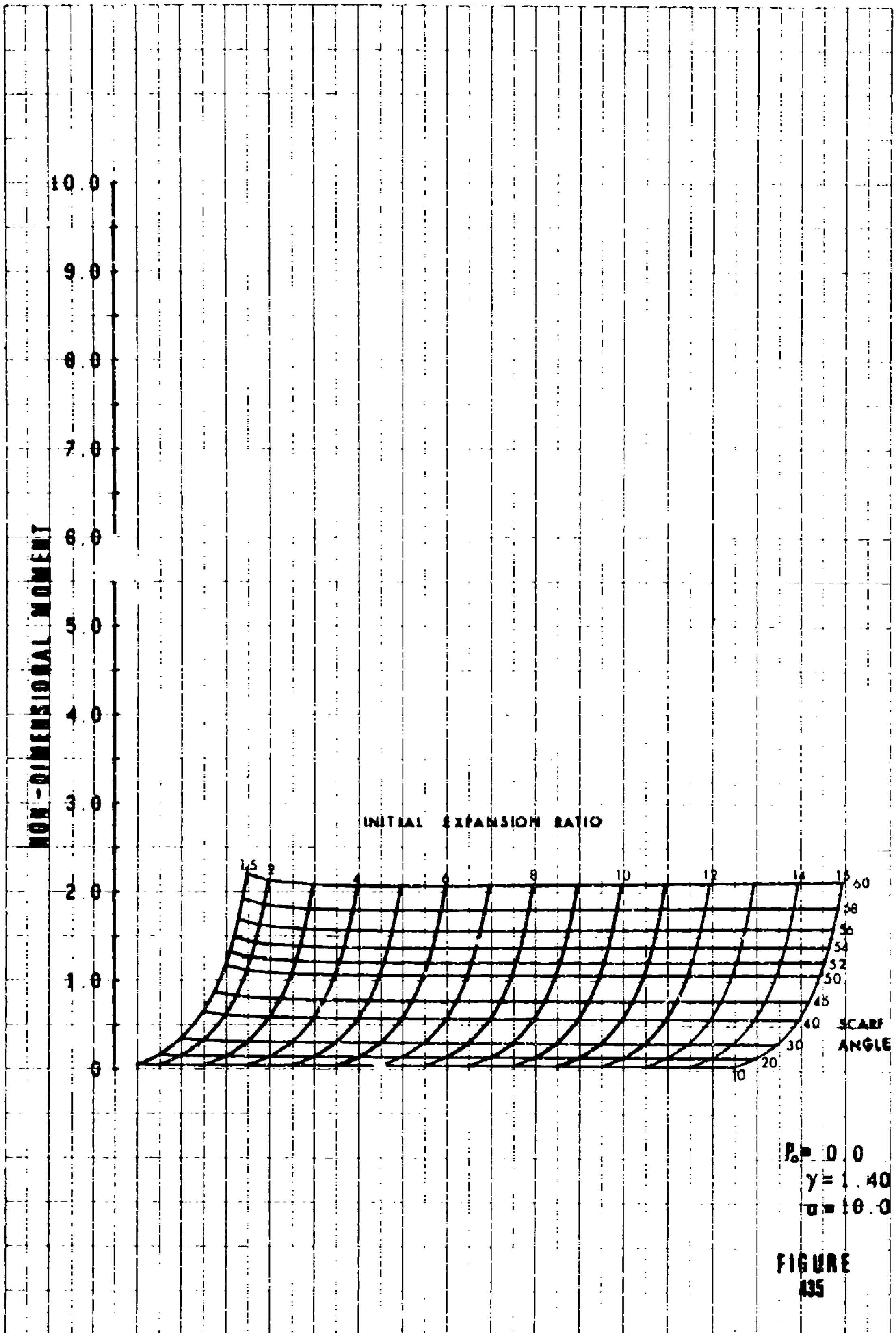

NON-DIMENSIONAL MOMENT
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
INITIAL EXPANSION RATIO
1.5
2
4
6
8
10
12
14
15
60
58
56
54
52
50
45
40
30
20
10
SCARF ANGLE
P_a = 0.0
γ = 1.40
σ = 10.0

FIGURE 435

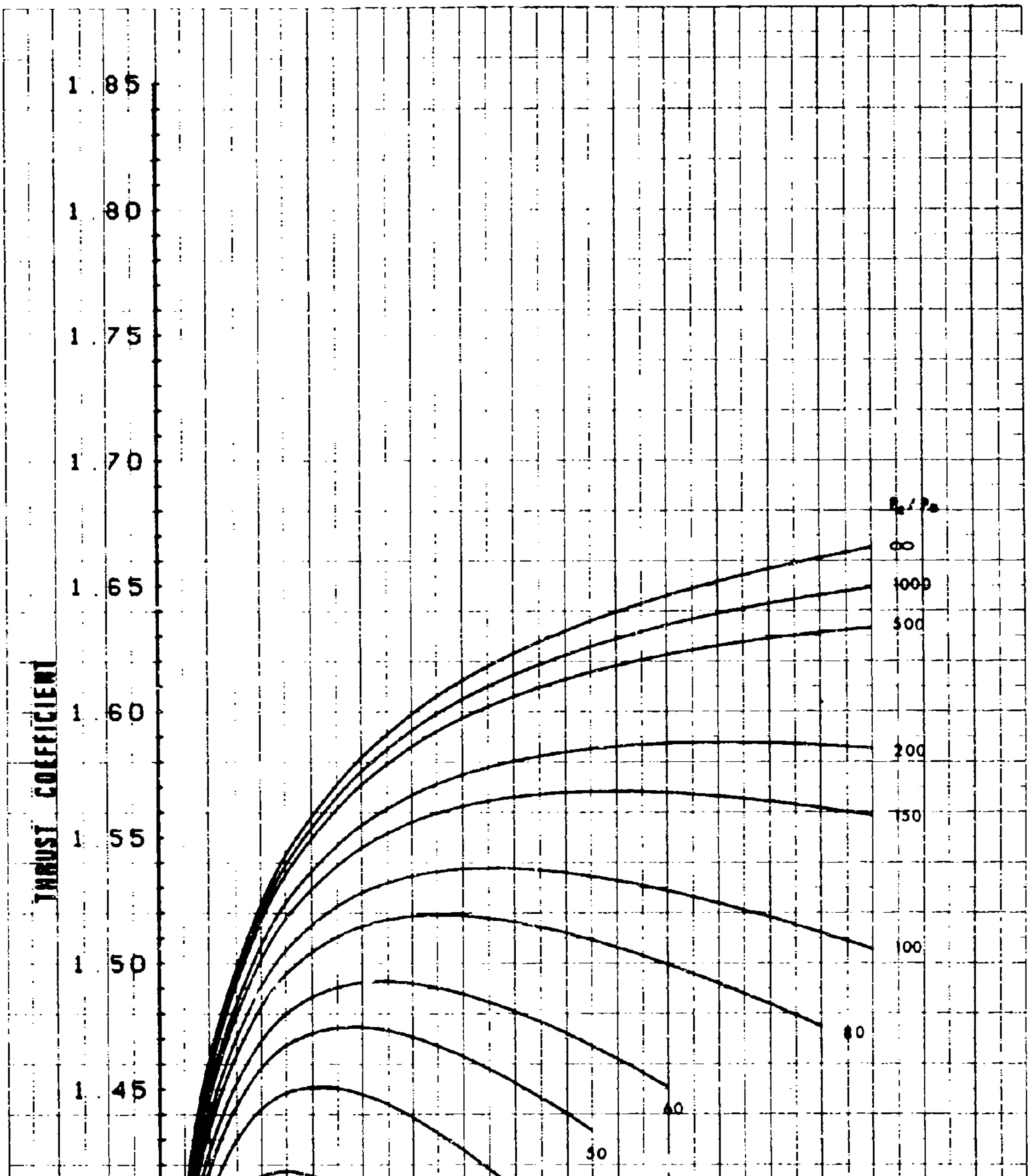

THRUST COEFFICIENT
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
INITIAL EXPANSION RATIO
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
P_c/P_a
∞
1000
500
200
150
100
80
60
50
40
30
20
$\phi = 10.0$
$\gamma = 1.40$
$\alpha = 10.0$

FIGURE 438

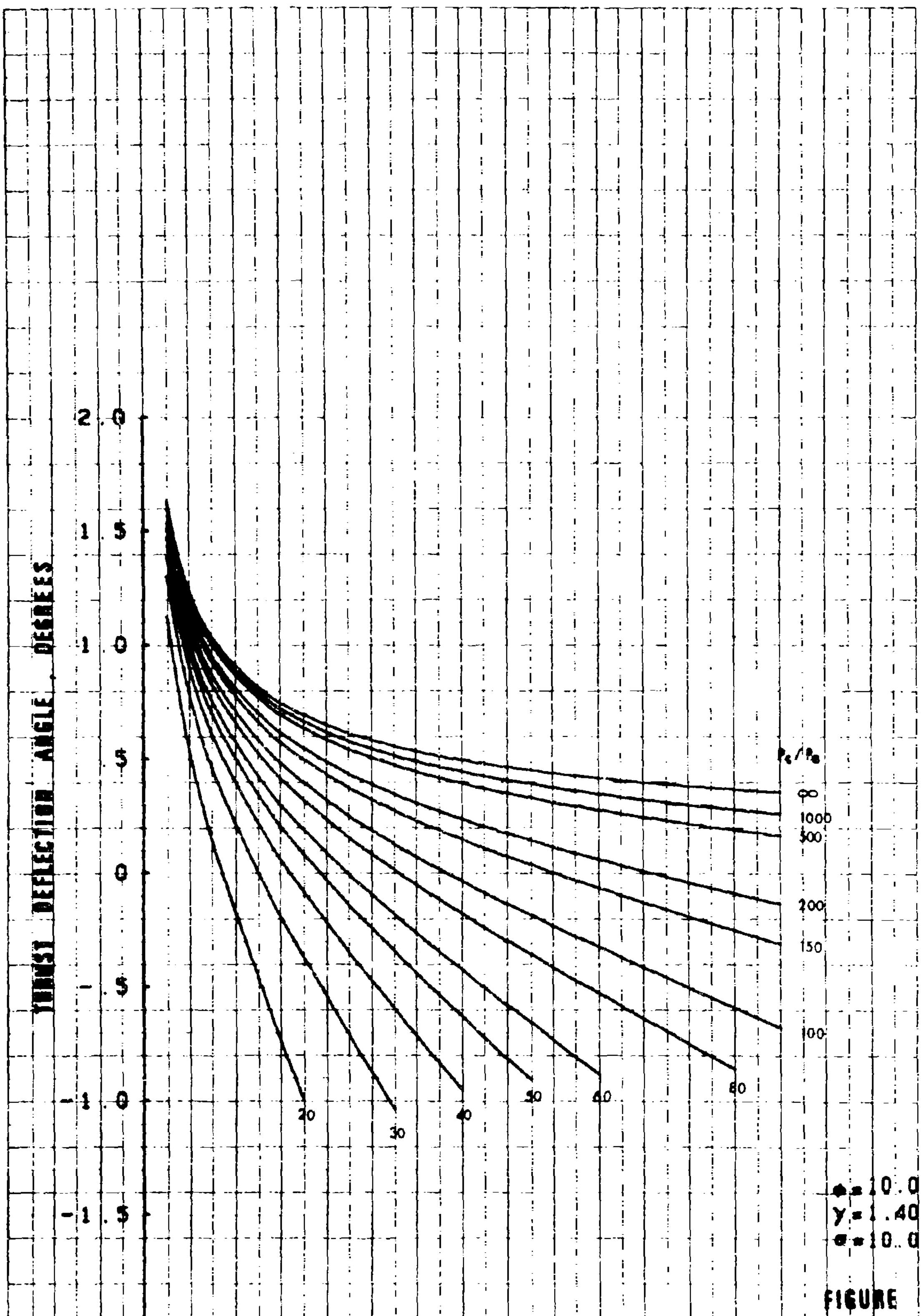
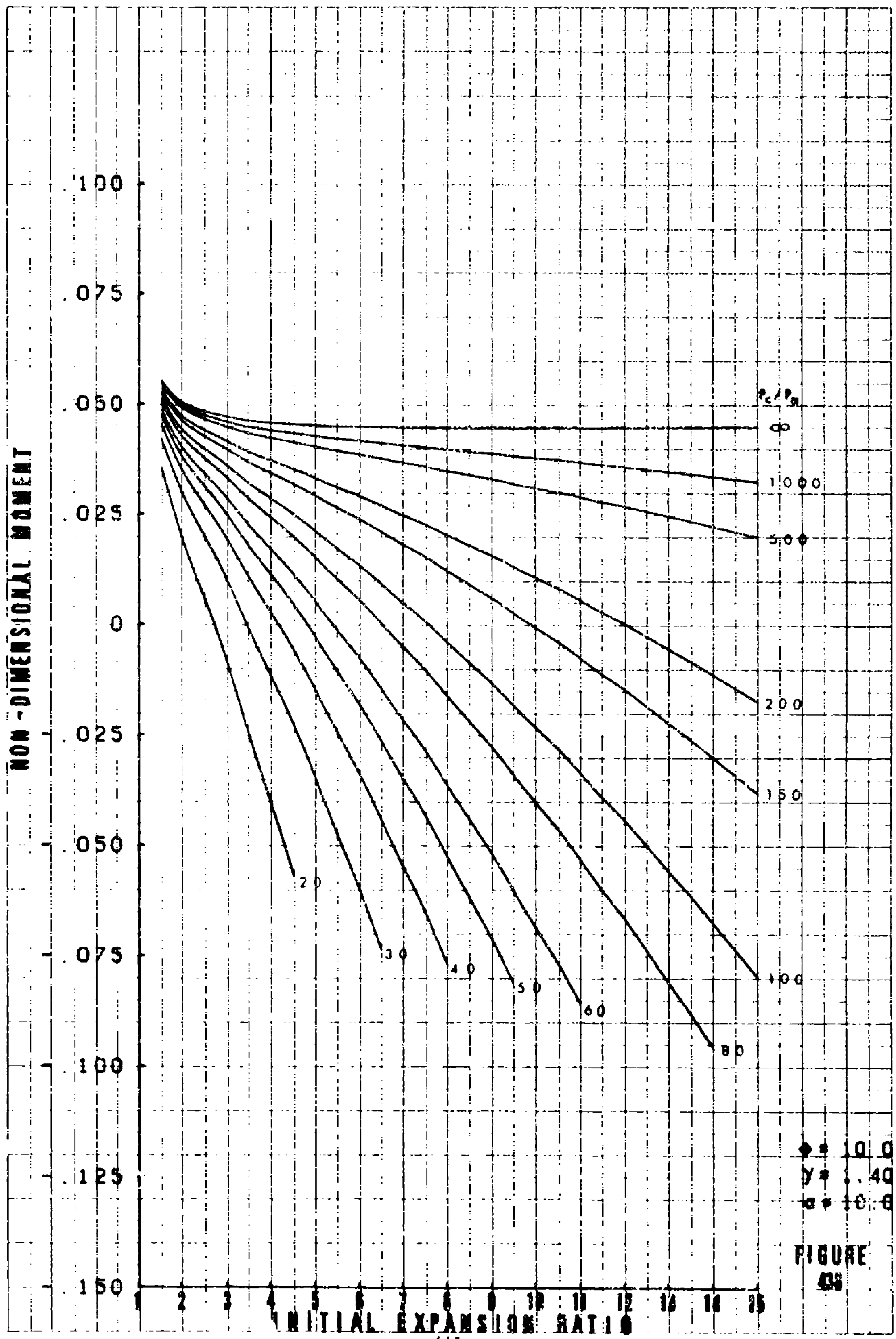

THRUST DEFLECTION ANGLE, DEGREES
2.0
1.5
1.0
.5
0
-.5
-1.0
-1.5
-2.0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
INITIAL EXPANSION RATIO
P_c/P_a
∞
1000
500
200
150
100
80
60
50
40
30
20
φ = 10.0
γ = 1.40
σ = 10.0

FIGURE 437


NON-DIMENSIONAL MOMENT
.100
.075
.050
.025
0
-.025
-.050
-.075
-.100
-.125
-.150
INITIAL EXPANSION RATIO
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
P_c/P_a
∞
1000
500
200
150
100
80
60
50
40
30
20
FIGURE

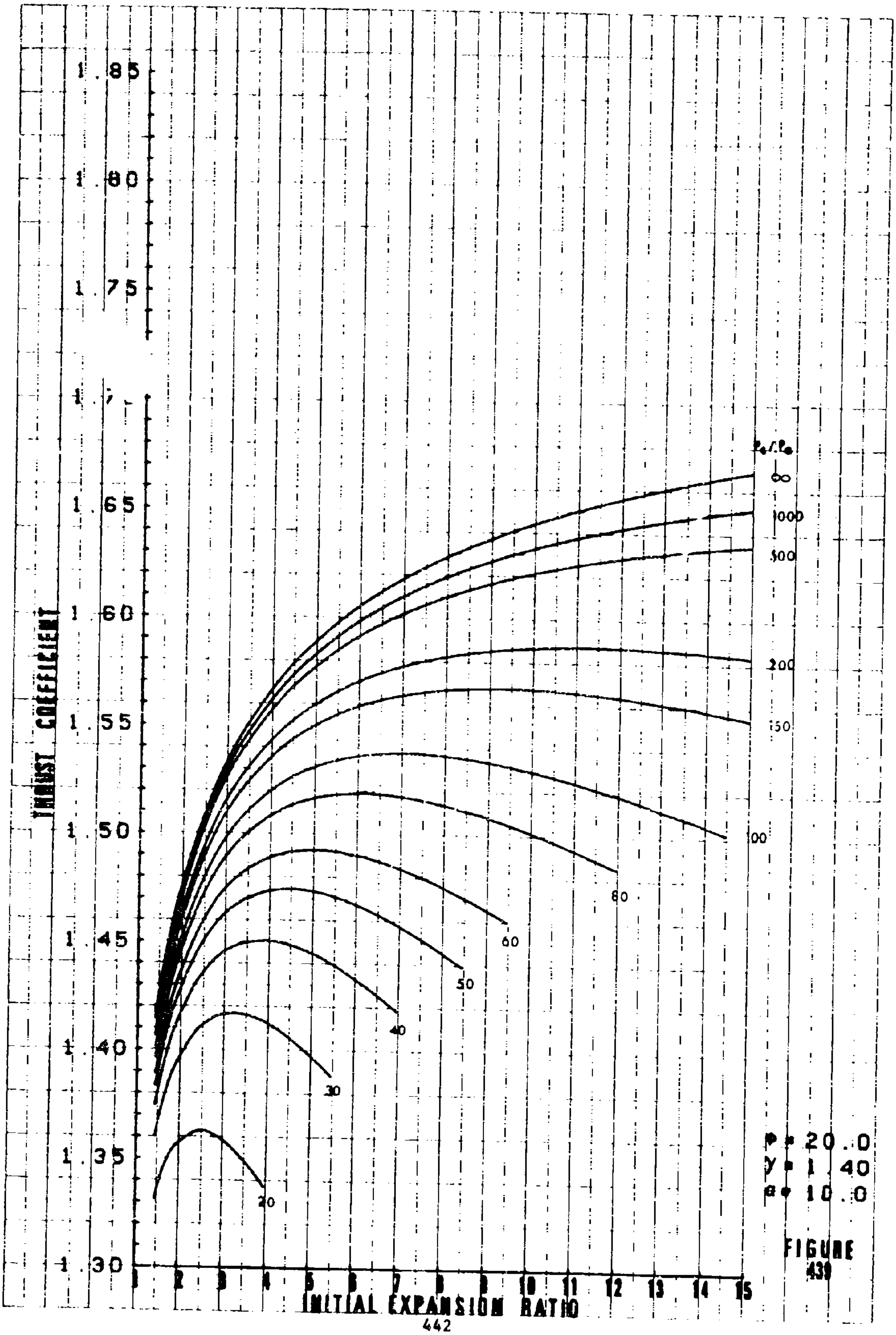

THRUST COEFFICIENT
1.85
1.80
1.75
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
INITIAL EXPANSION RATIO
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
∞
1000
500
200
150
100
80
60
50
40
30
20
P = 20.0
γ = 1.40
a = 10.0

FIGURE 439

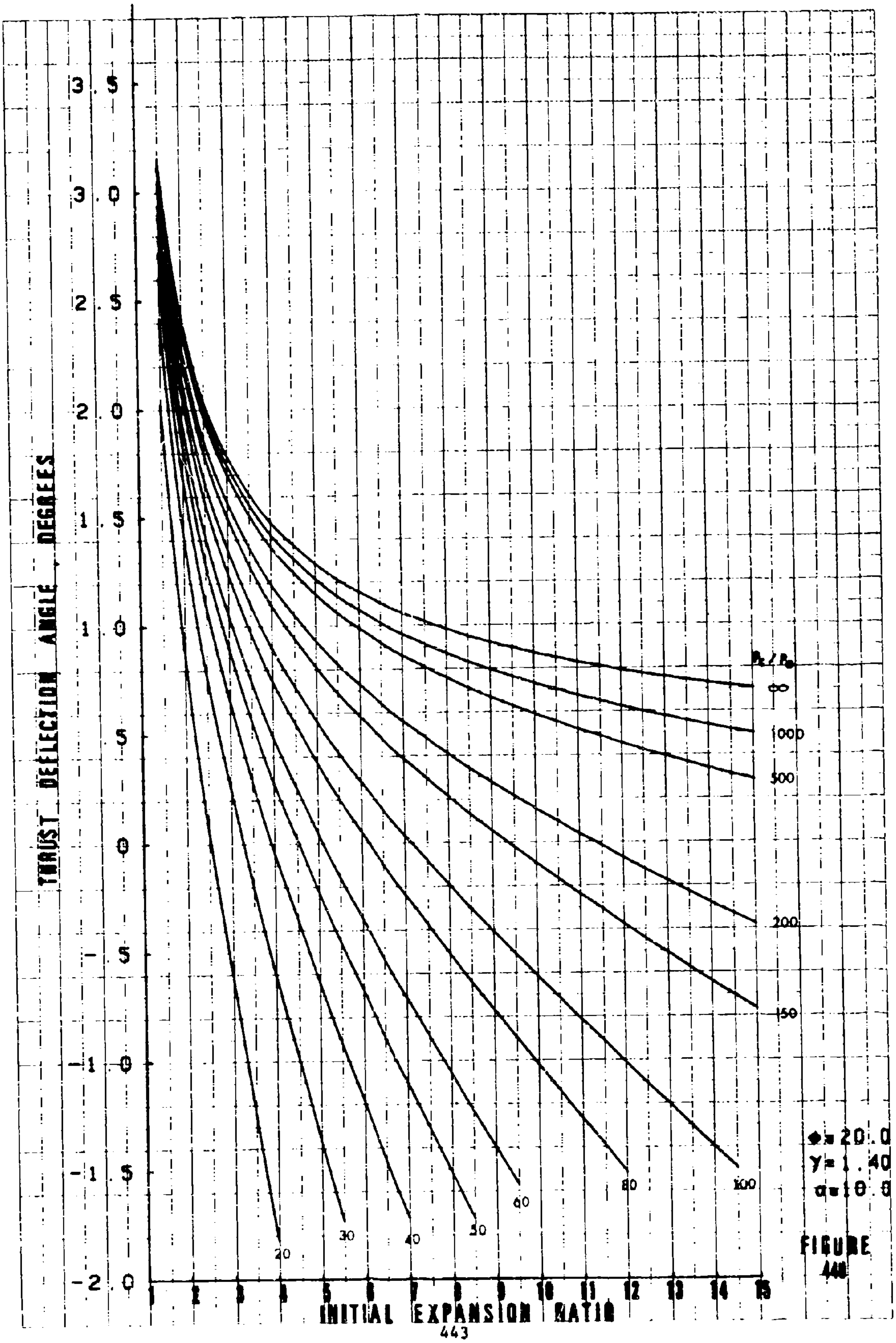
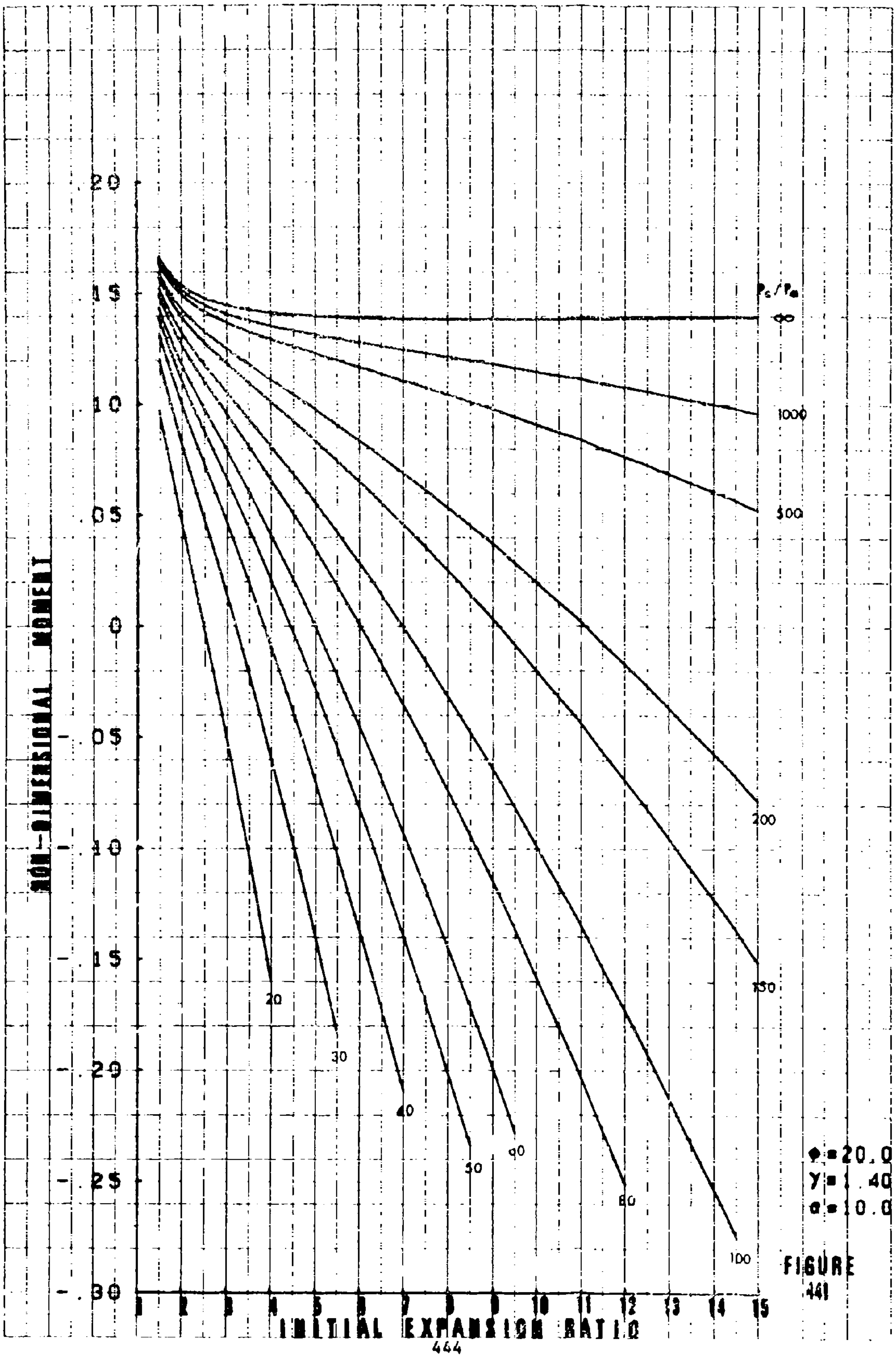

THRUST DEFLECTION ANGLE, DEGREES
3.5
3.0
2.5
2.0
1.5
1.0
.5
0
-.5
-1.0
-1.5
-2.0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
P_c/P_a
∞
1000
500
200
150
100
80
60
50
40
30
20
Φ=20.0
γ=1.40
α=18.0

FIGURE 440


NON-DIMENSIONAL MOMENT
INITIAL EXPANSION RATIO
.20
.15
.10
.05
0
-.05
-.10
-.15
-.20
-.25
-.30
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
P_c/P_a
∞
1000
500
200
150
100
80
60
50
40
30
20
φ = 20.0
γ = 1.40
α = 10.0
FIGURE 441

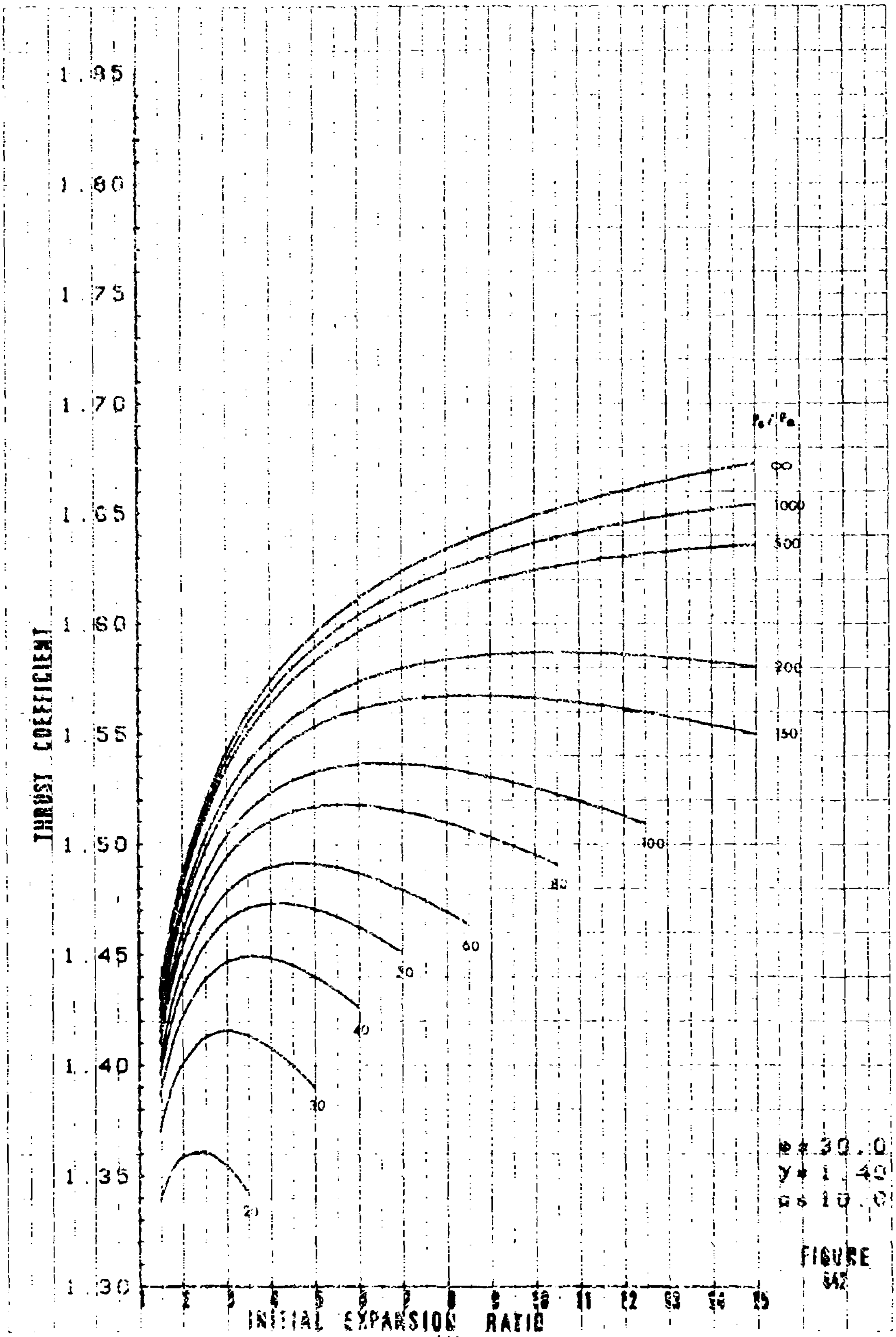
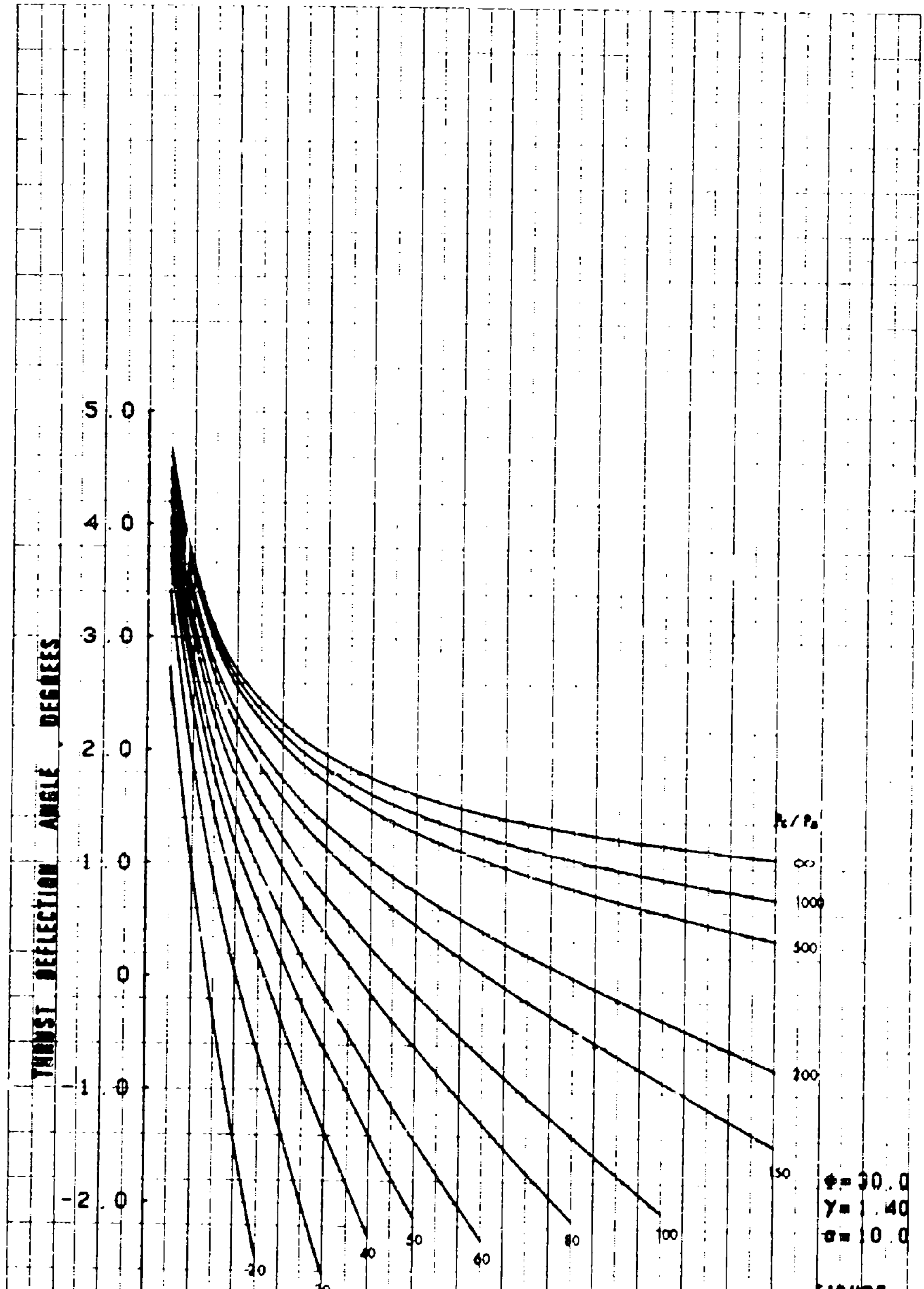
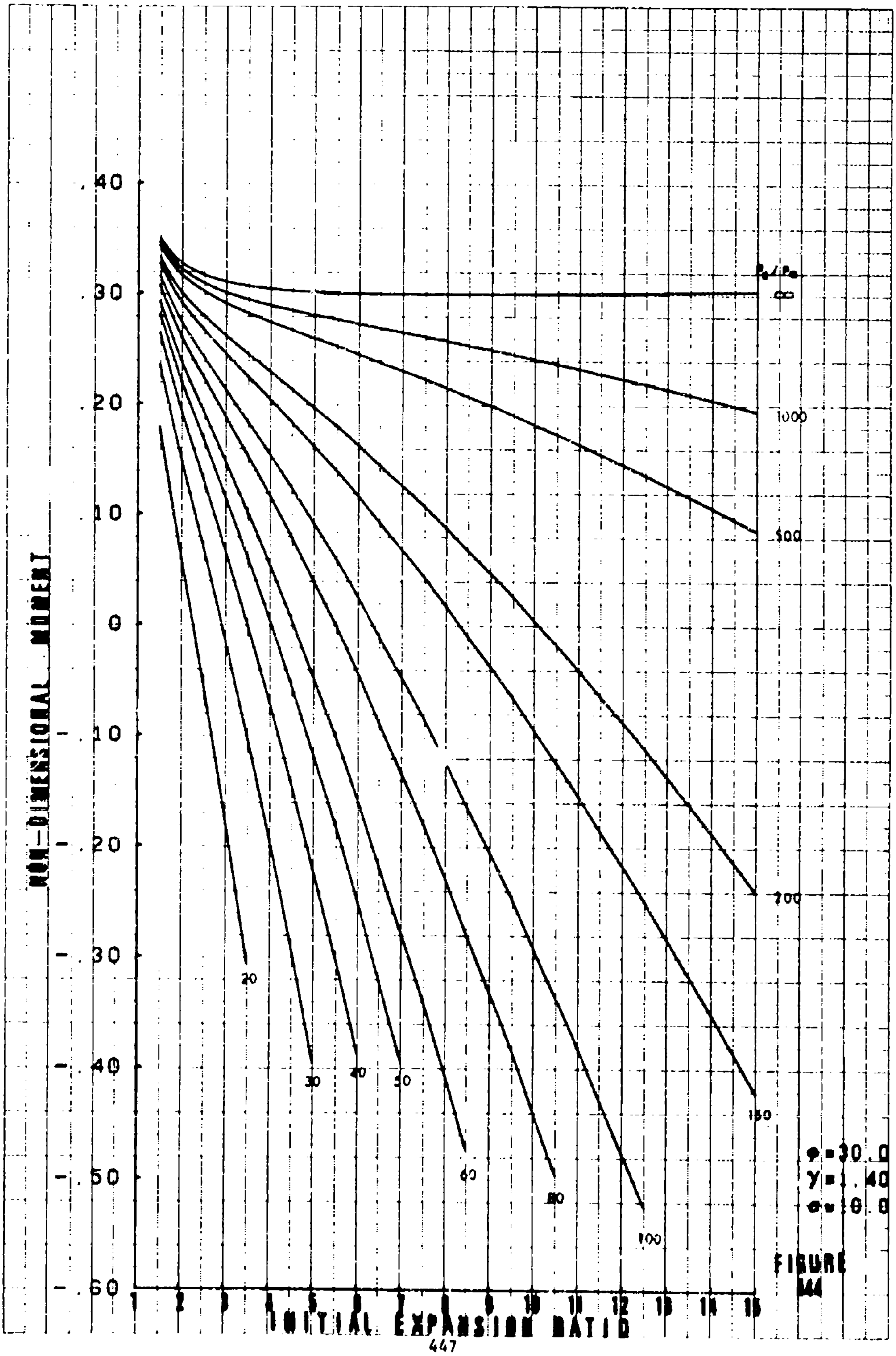
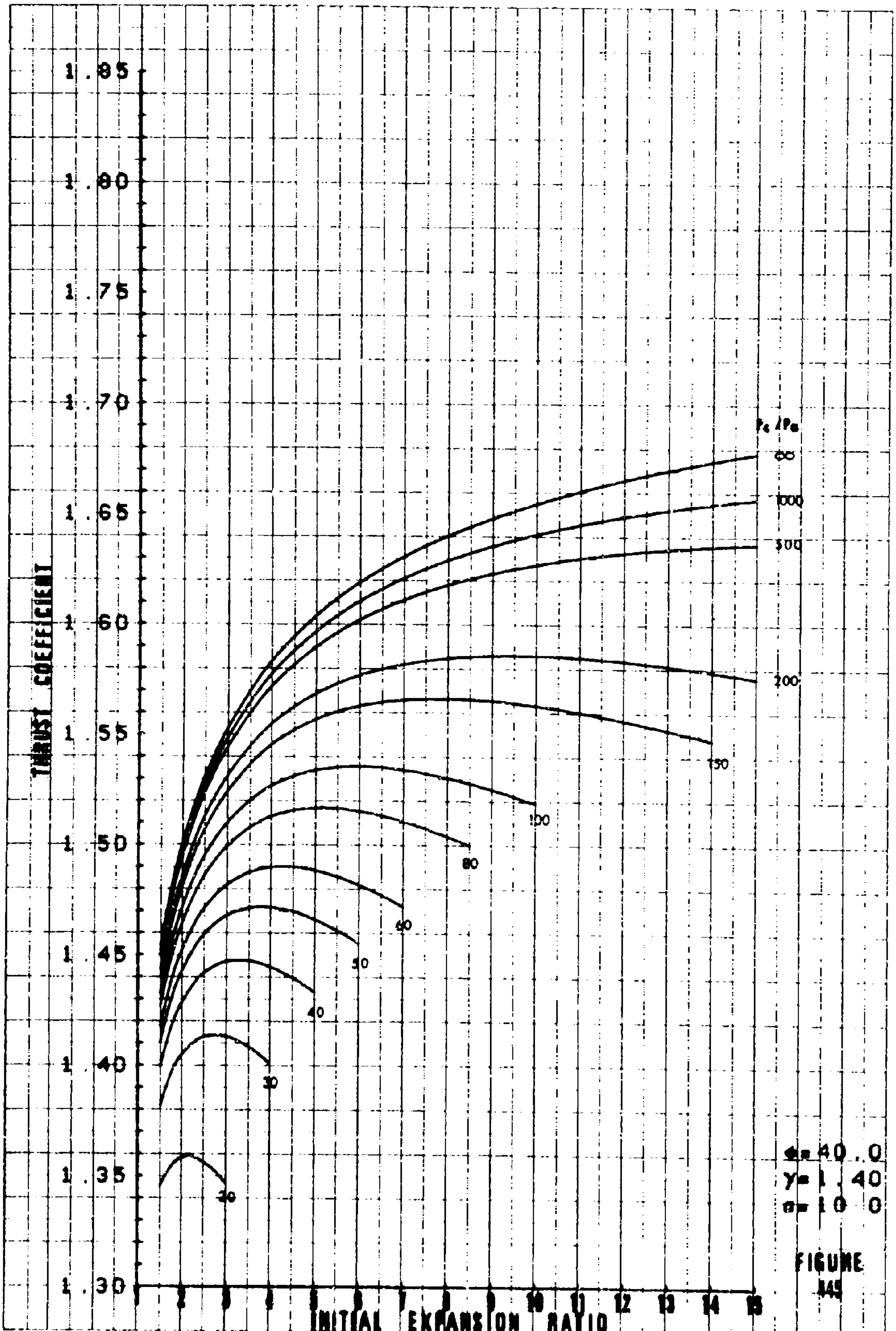

THRUST COEFFICIENT
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
INITIAL EXPANSION RATIO
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
P_c/P_a
∞
1000
500
200
150
100
80
60
50
40
30
20
θ = 30.0
γ = 1.40
α = 10.0

FIGURE 442

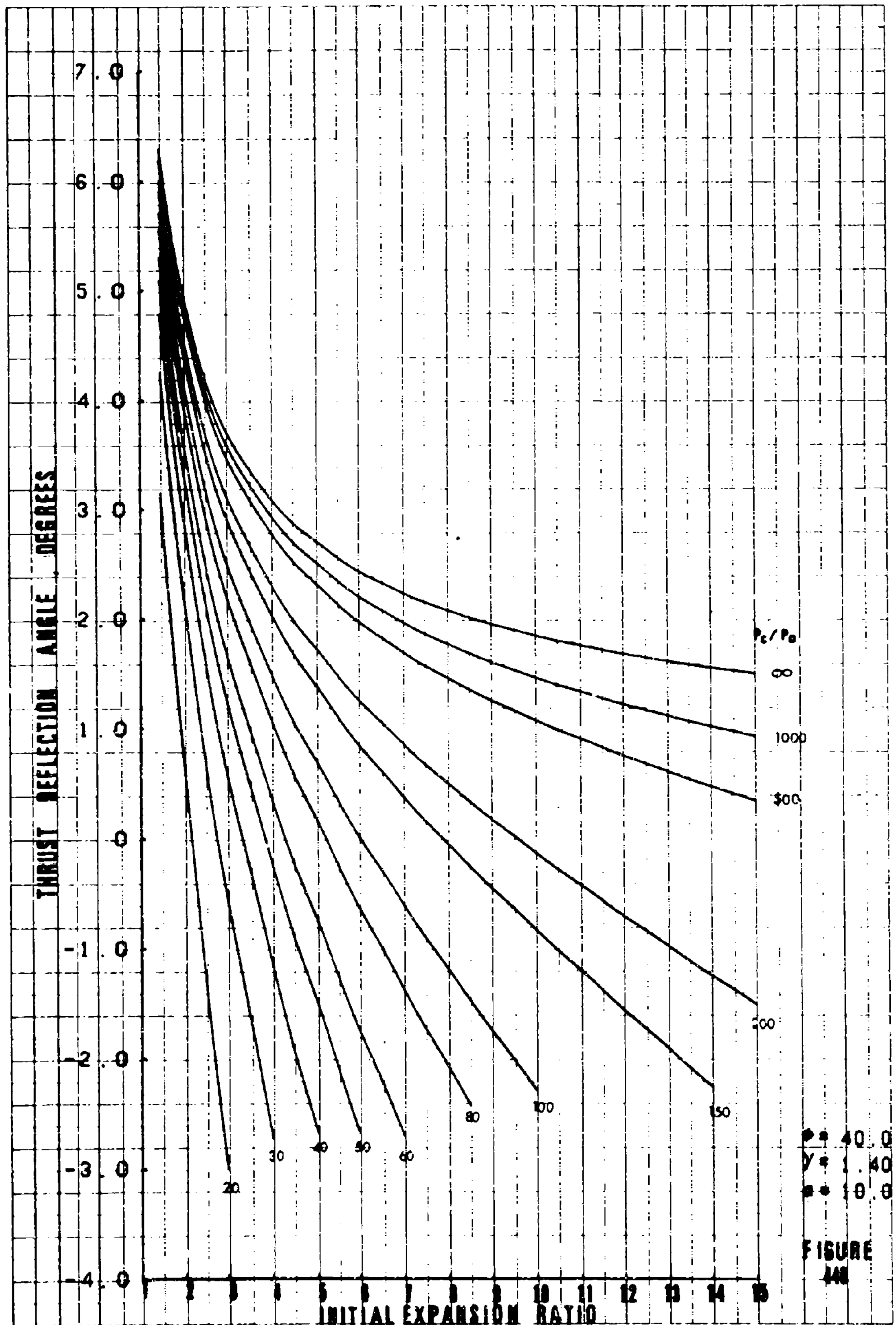

THRUST DEFLECTION ANGLE DEGREES
5.0
4.0
3.0
2.0
1.0
0
-1.0
-2.0
-3.0
INITIAL EXPANSION RATIO
P_c/P_a
∞
1000
500
200
150
100
80
60
50
40
30
20
φ= 30.0
γ= 1.40
α= 10.0
FIGURE 443


NON-DIMENSIONAL MOMENT
INITIAL EXPANSION RATIO
P_0/P_a
∞
1000
500
200
150
100
80
60
50
40
30
20
φ = 30.0
γ = 1.40
σ = 0.0
FIGURE 344

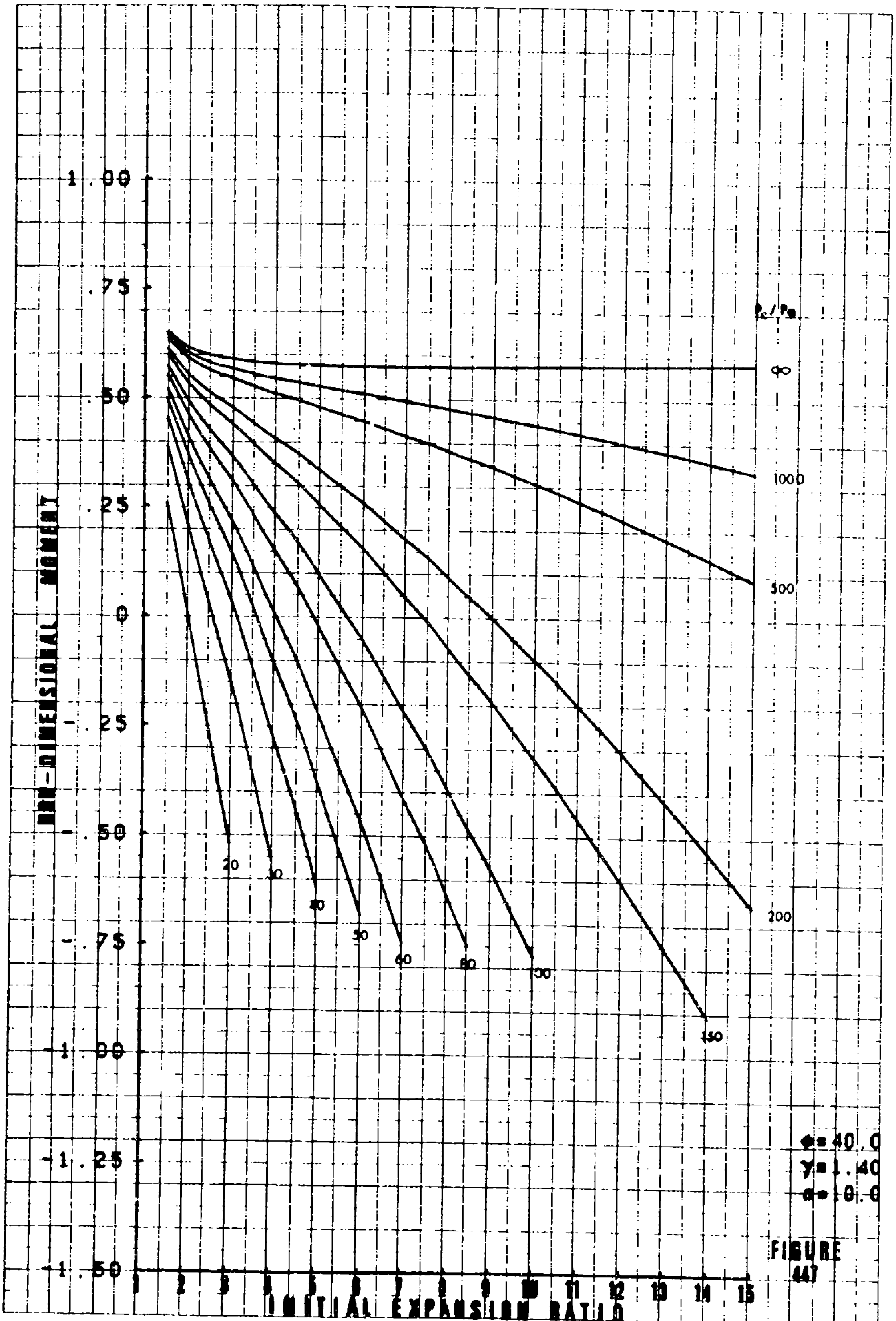


1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
THRUST COEFFICIENT
INITIAL EXPANSION RATIO
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
P_c/P_a
∞
1000
500
200
150
100
80
60
50
40
30
20
α= 40.0
γ= 1.40
θ= 10.0

FIGURE 445

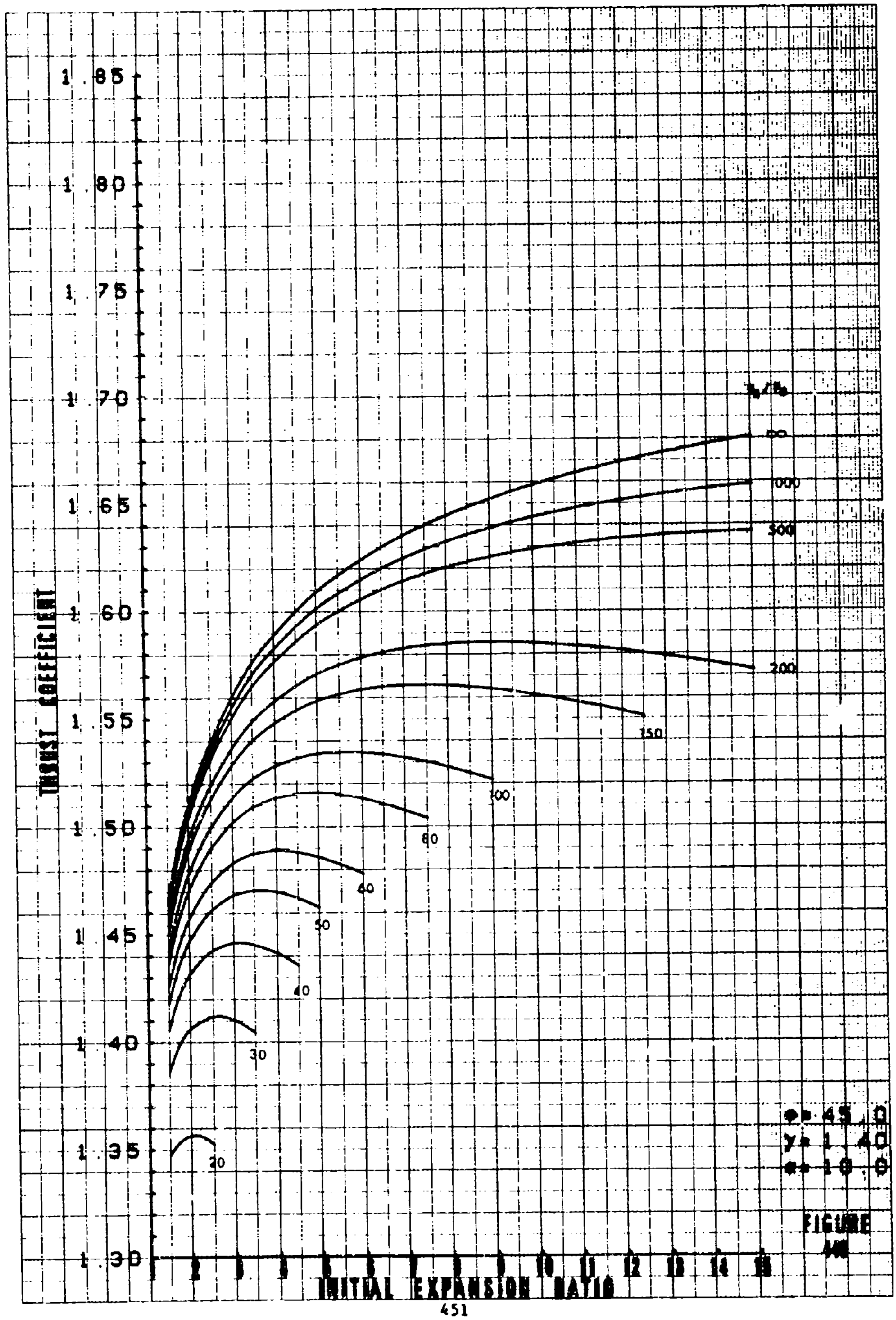


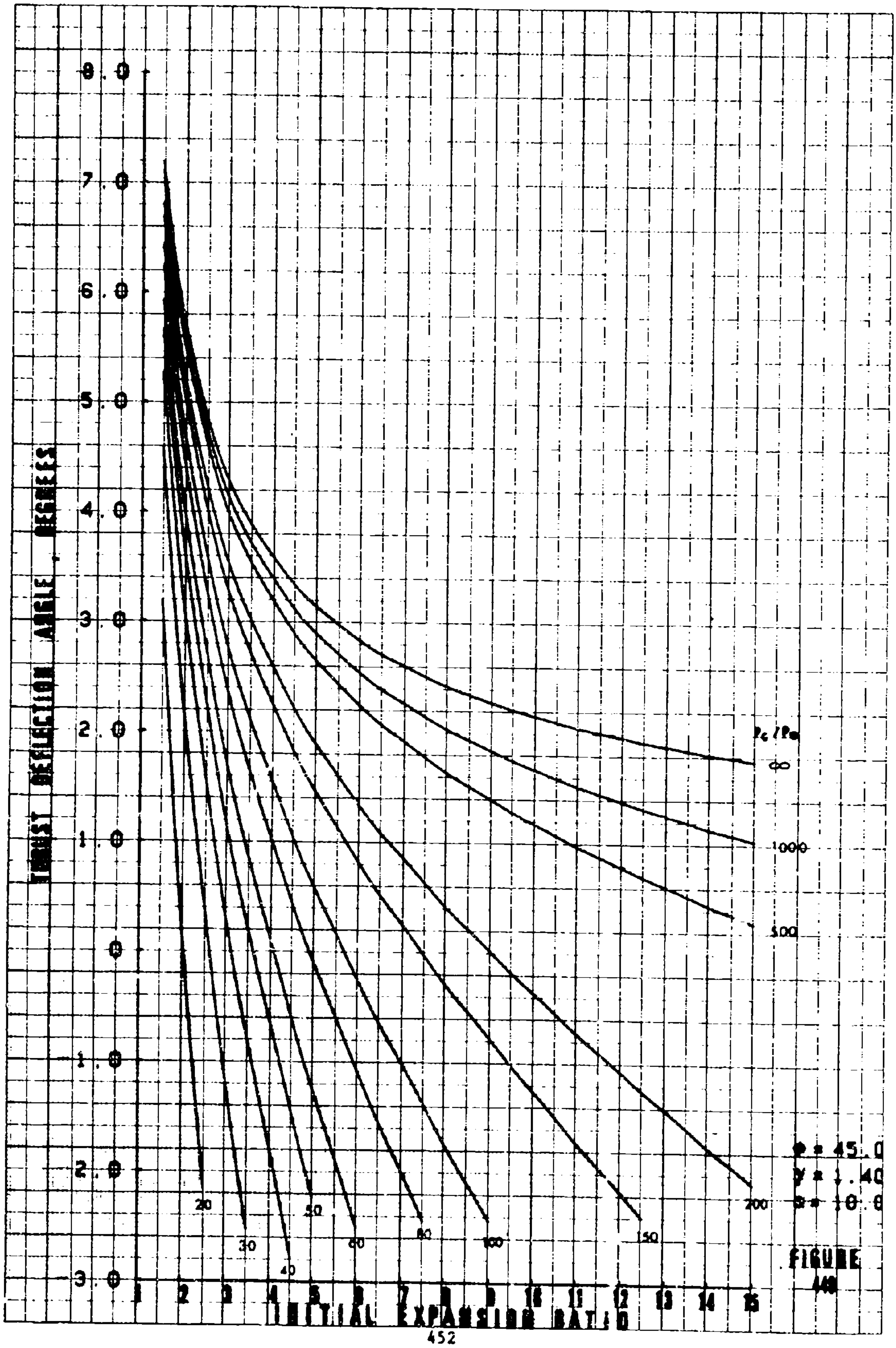
THRUST DEFLECTION ANGLE, DEGREES
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
-1.0
-2.0
-3.0
-4.0
INITIAL EXPANSION RATIO
P_c/P_a
∞
1000
500
200
150
100
80
60
50
40
30
20

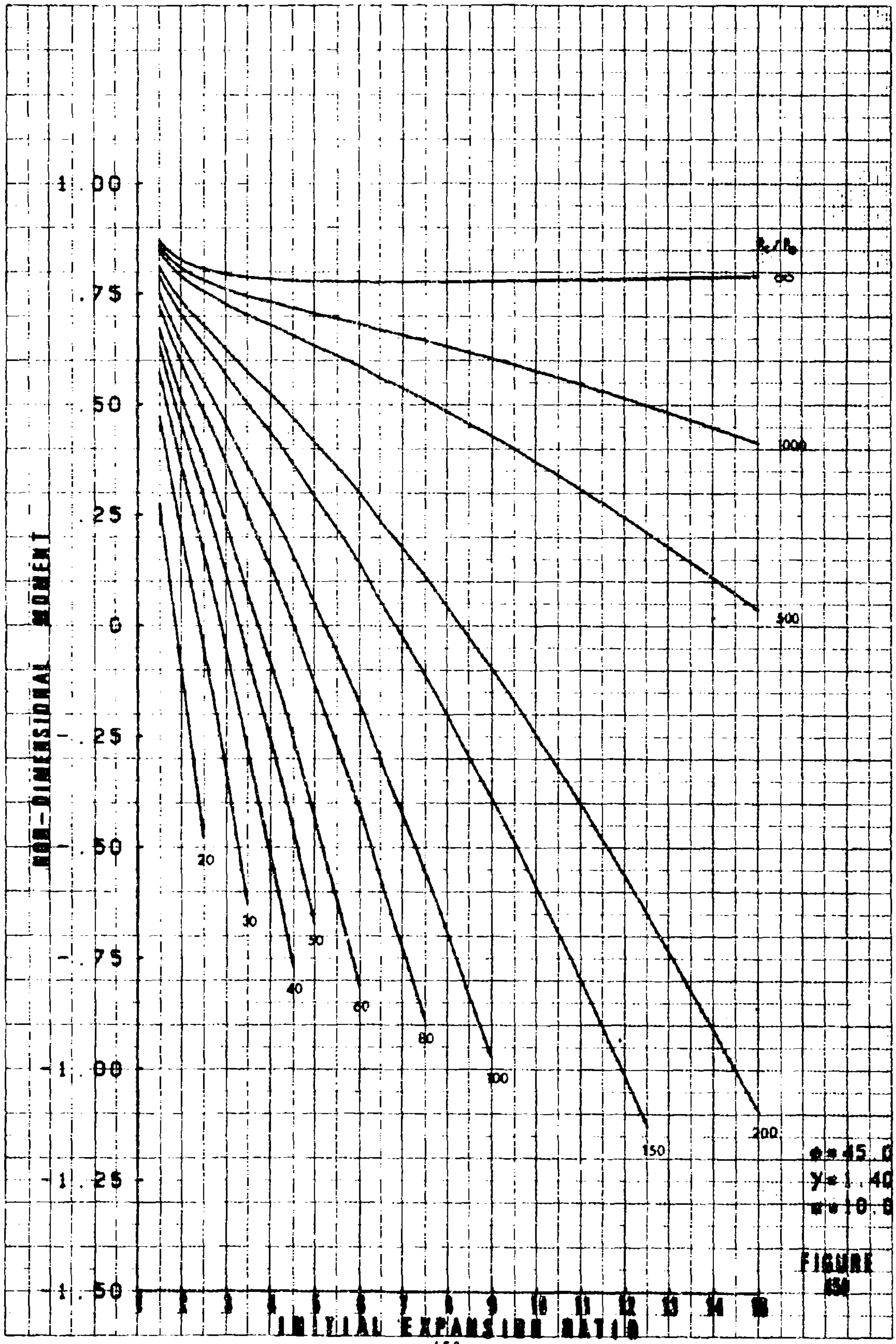


1.00
.75
.50
.25
0
-.25
-.50
-.75
-1.00
-1.25
-1.50
NON-DIMENSIONAL MOMENT
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
INITIAL EXPANSION RATIO
P_c/P_a
∞
1000
500
200
150
100
80
60
50
40
30
20
φ = 40.0
γ = 1.40
α = 0.0

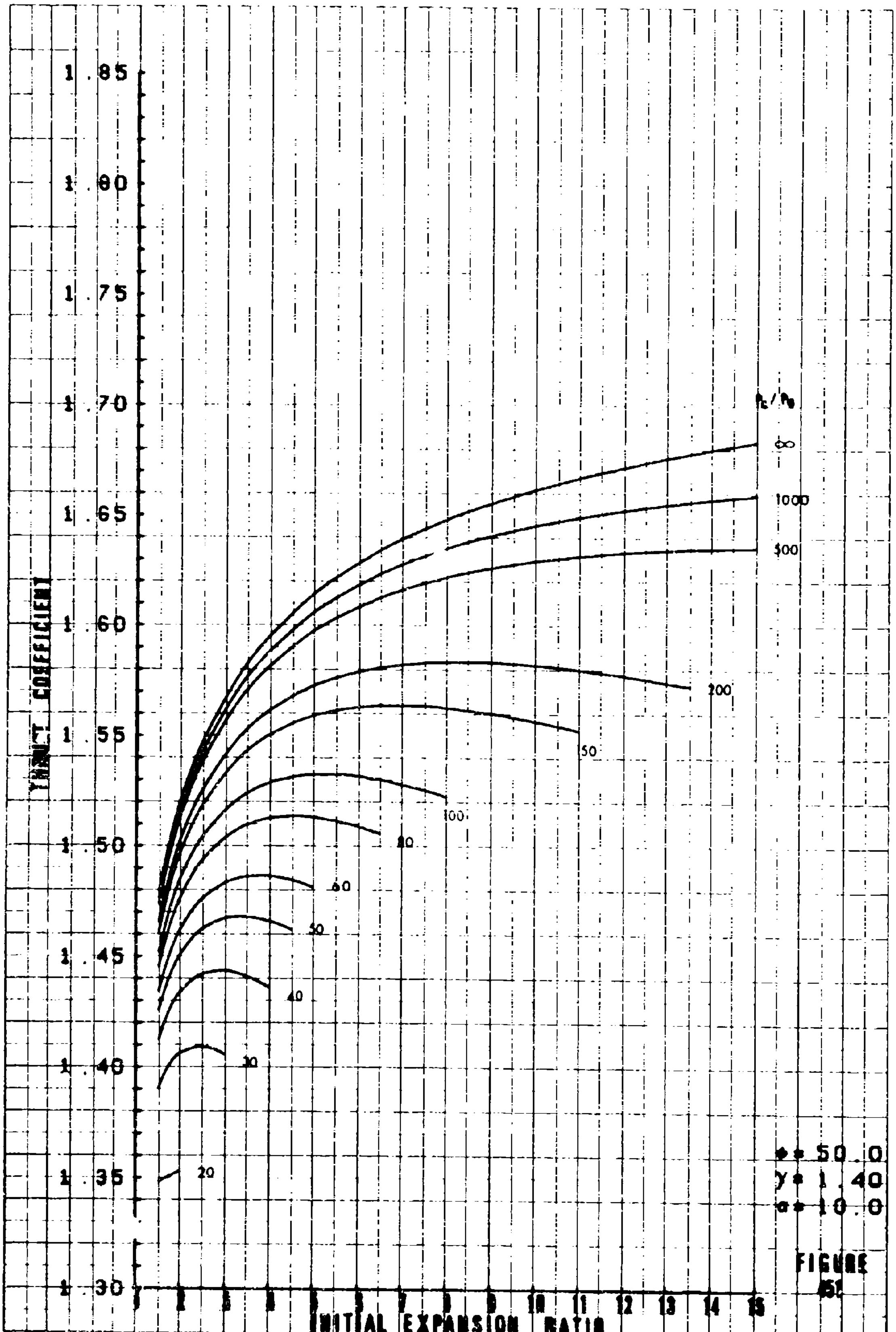
FIGURE 447

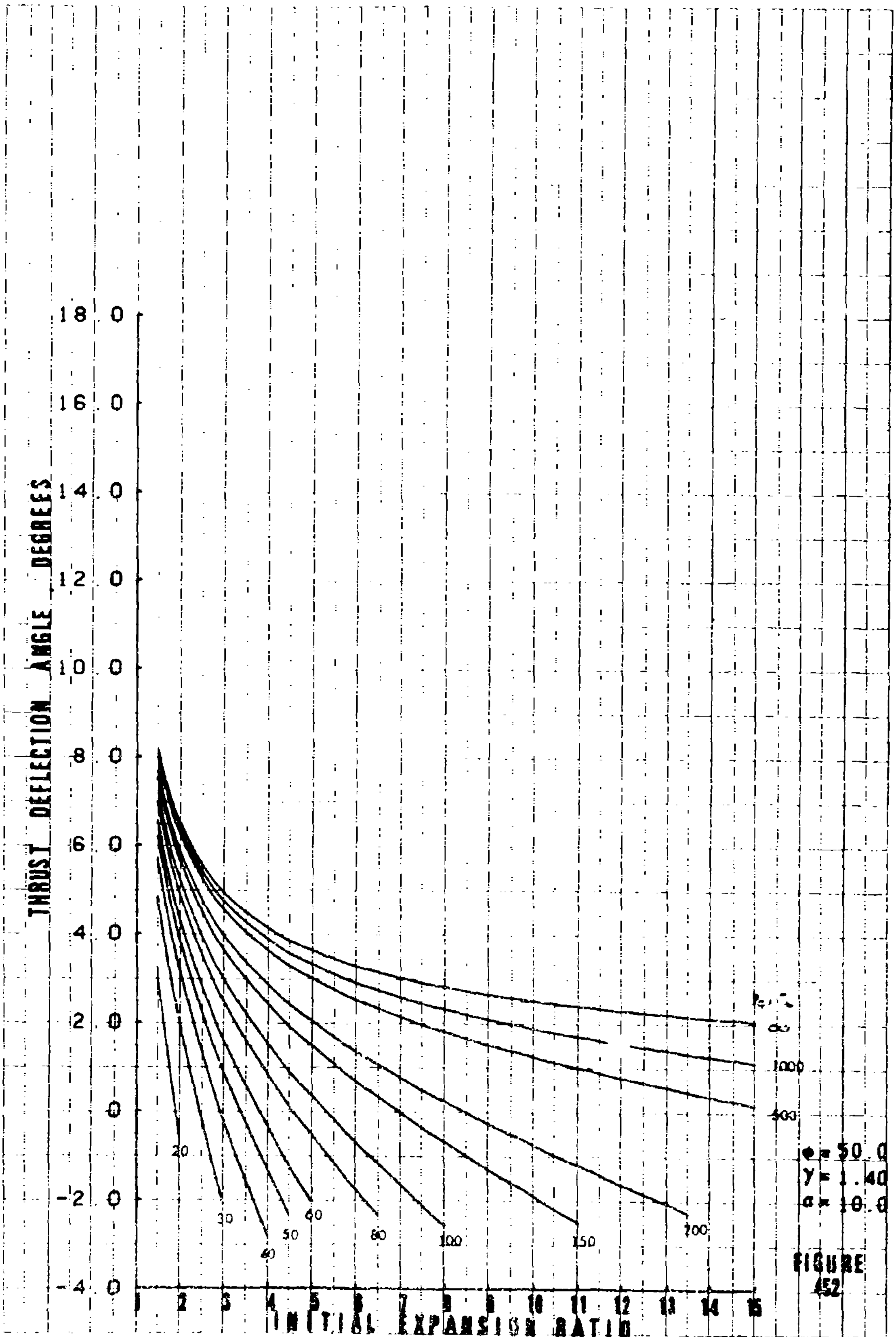

1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
THRUST COEFFICIENT
INITIAL EXPANSION RATIO
1000
500
200
150
100
80
60
50
40
30
20
= 45.0
γ= 1.40
= 10.0
FIGURE


THRUST DEFLECTION ANGLE, DEGREES
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
1.0
2.0
3.0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
P_c/P_a
∞
1000
500
200
150
100
80
60
50
40
30
20
ϕ = 45.0
γ = 1.40
θ = 10.0
FIGURE



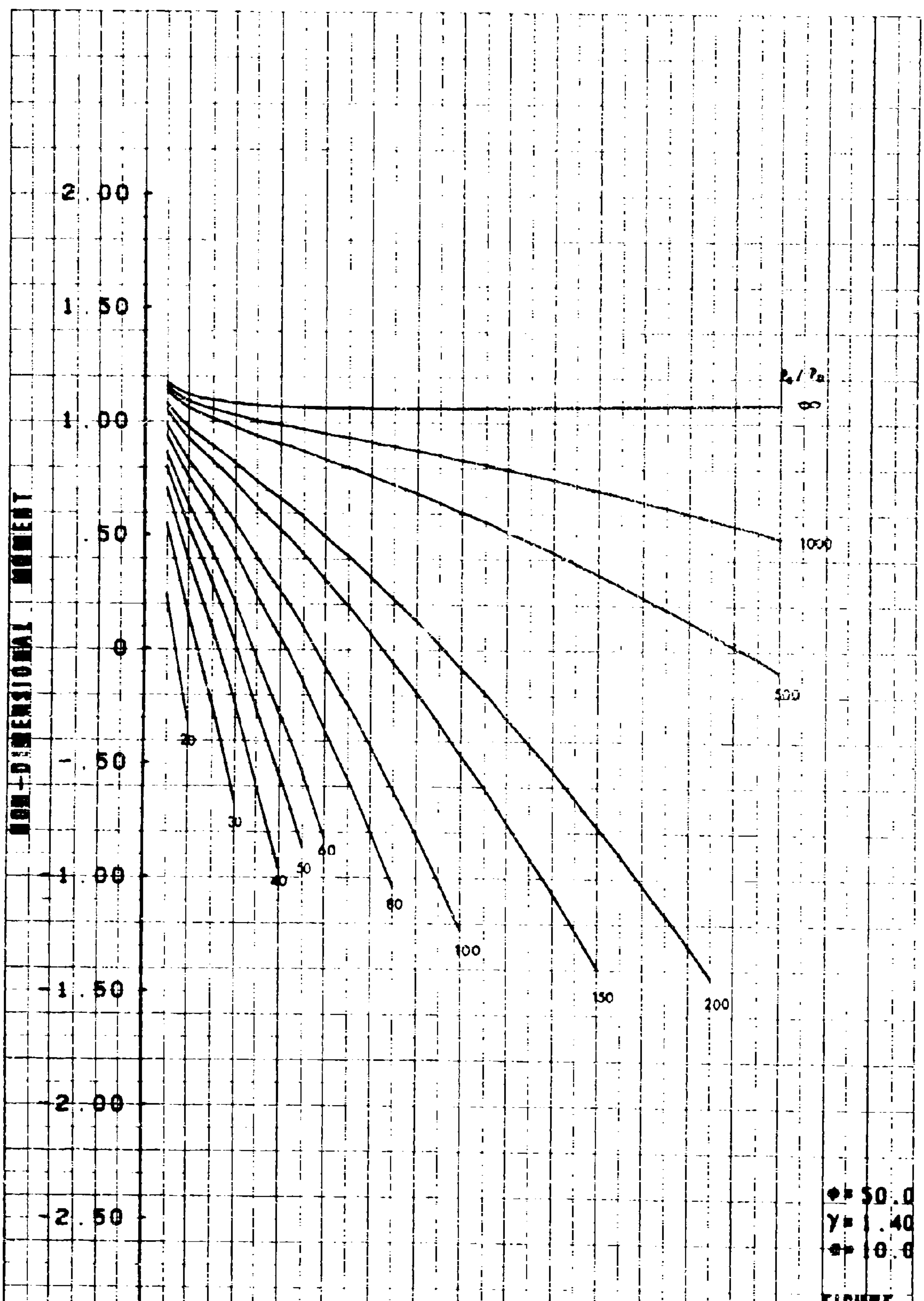
NON-DIMENSIONAL MOMENT
1.00
.75
.50
.25
0
-.25
-.50
-.75
-1.00
-1.25
-1.50
INITIAL EXPANSION RATIO
∞
1000
500
200
150
100
80
60
50
40
30
20
FIGURE

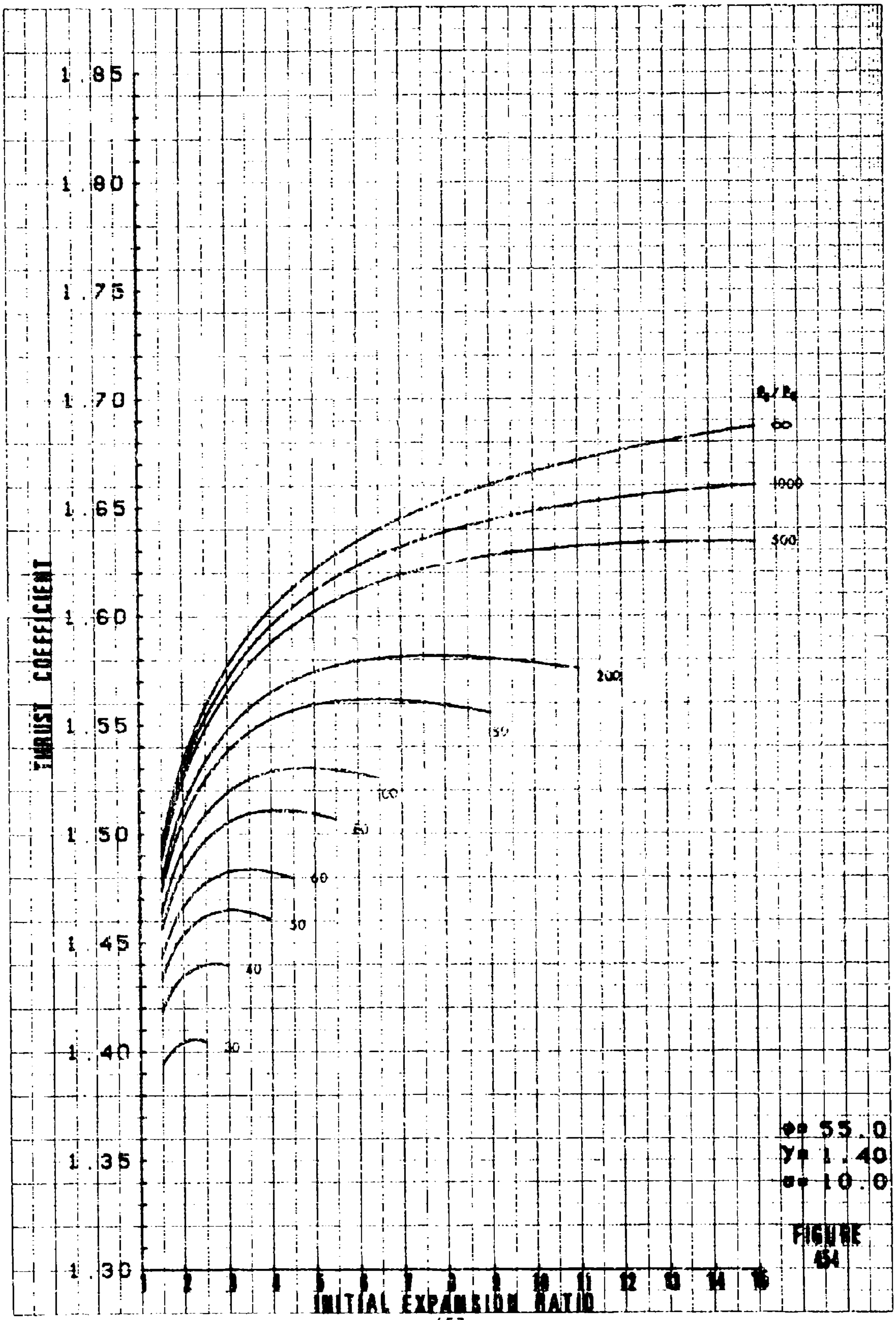

THRUST COEFFICIENT
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
INITIAL EXPANSION RATIO
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
∞
1000
500
200
150
100
80
60
50
40
30
20
φ= 50.0
γ= 1.40
α= 10.0
FIGURE 451



THRUST DEFLECTION ANGLE DEGREES
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0
-2.0
-4.0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
20
30
40
50
60
80
100
150
200
500
1000
∞
φ = 50.0
γ = 1.40
α = 10.0

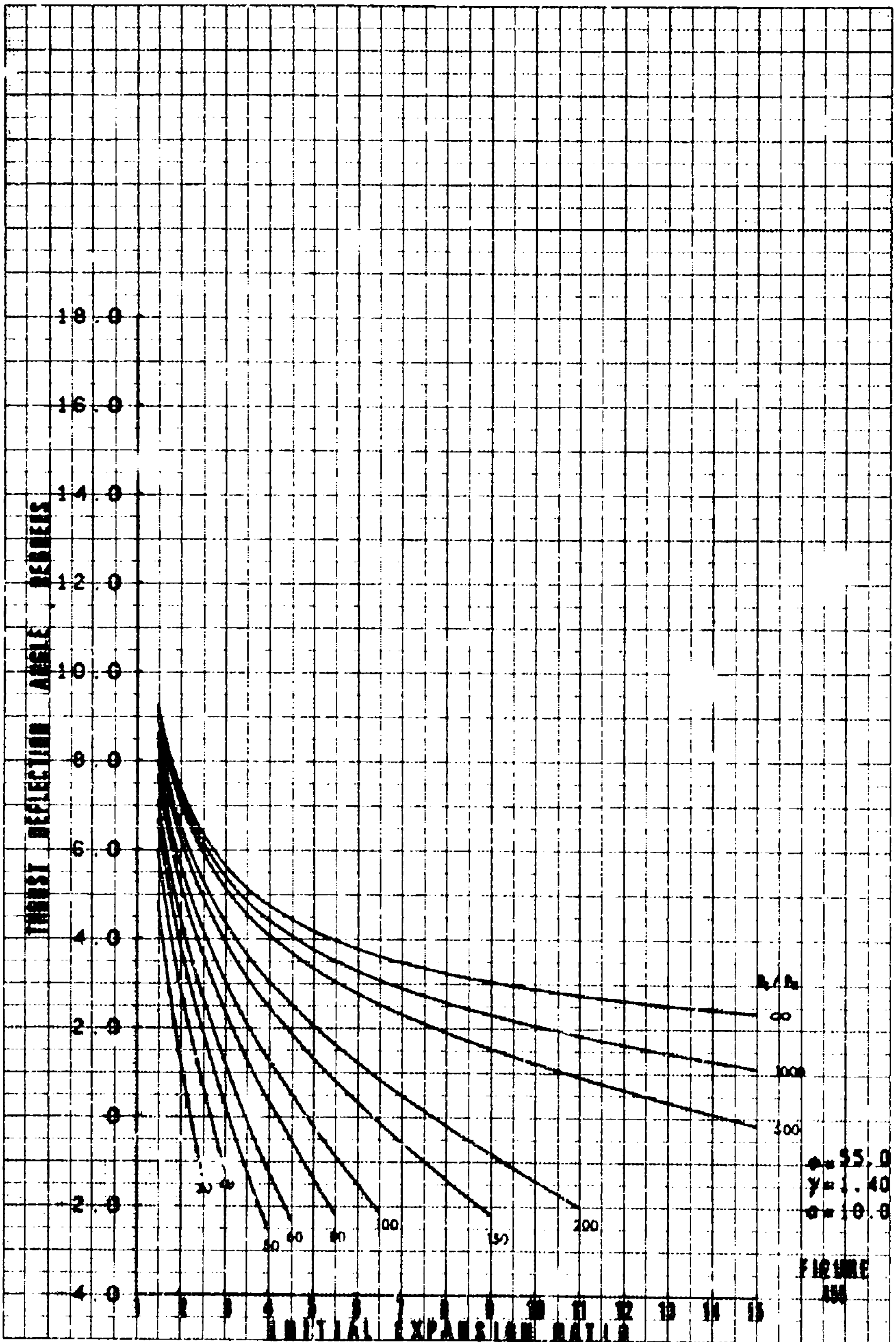
FIGURE 452

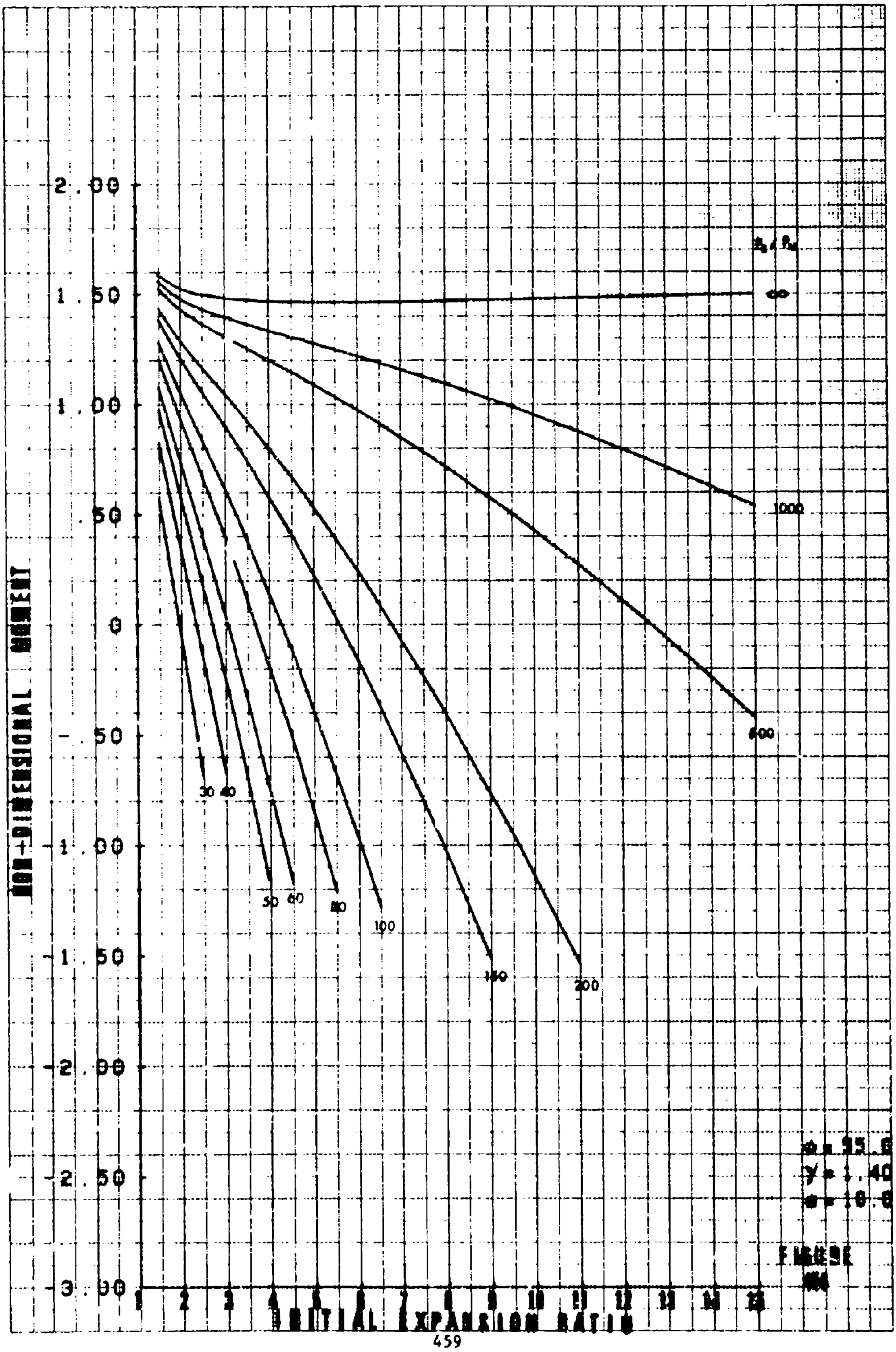

2.00
1.50
1.00
.50
0
-.50
-1.00
-1.50
-2.00
-2.50
-3.00
NON-DIMENSIONAL MOMENT
INITIAL EXPANSION RATIO
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
p_c/p_a
∞
1000
500
200
150
100
80
60
50
40
30
20
Φ= 50.0
γ= 1.40
θ= 10.0
FIGURE 453



1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
THRUST COEFFICIENT
INITIAL EXPANSION RATIO
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
∞
1000
500
200
150
100
60
50
40
30
φ= 55.0
γ= 1.40
σ= 10.0

FIGURE 454


THRUST DEFLECTION ANGLE, DEGREES
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0
-2.0
-4.0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
∞
1000
300
200
150
100
80
60
50
40
30
φ = 55.0
γ = 1.40
θ = 10.0
FIGURE


NON-DIMENSIONAL MOMENT
INITIAL EXPANSION RATIO
2.00
1.50
1.00
.50
0
-.50
-1.00
-1.50
-2.00
-2.50
-3.00
30
40
50
60
80
100
150
200
500
1000
∞
FIGURE

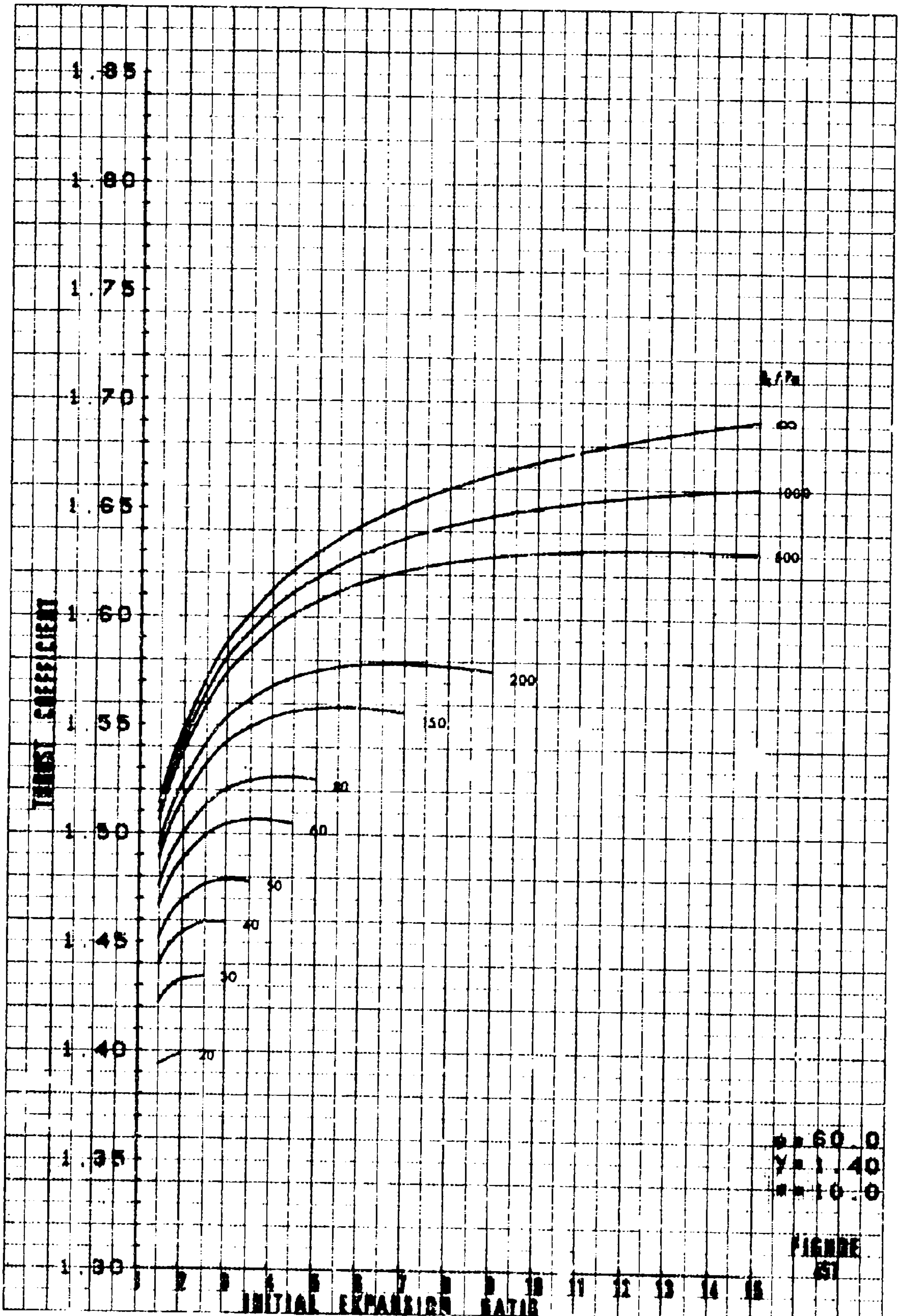
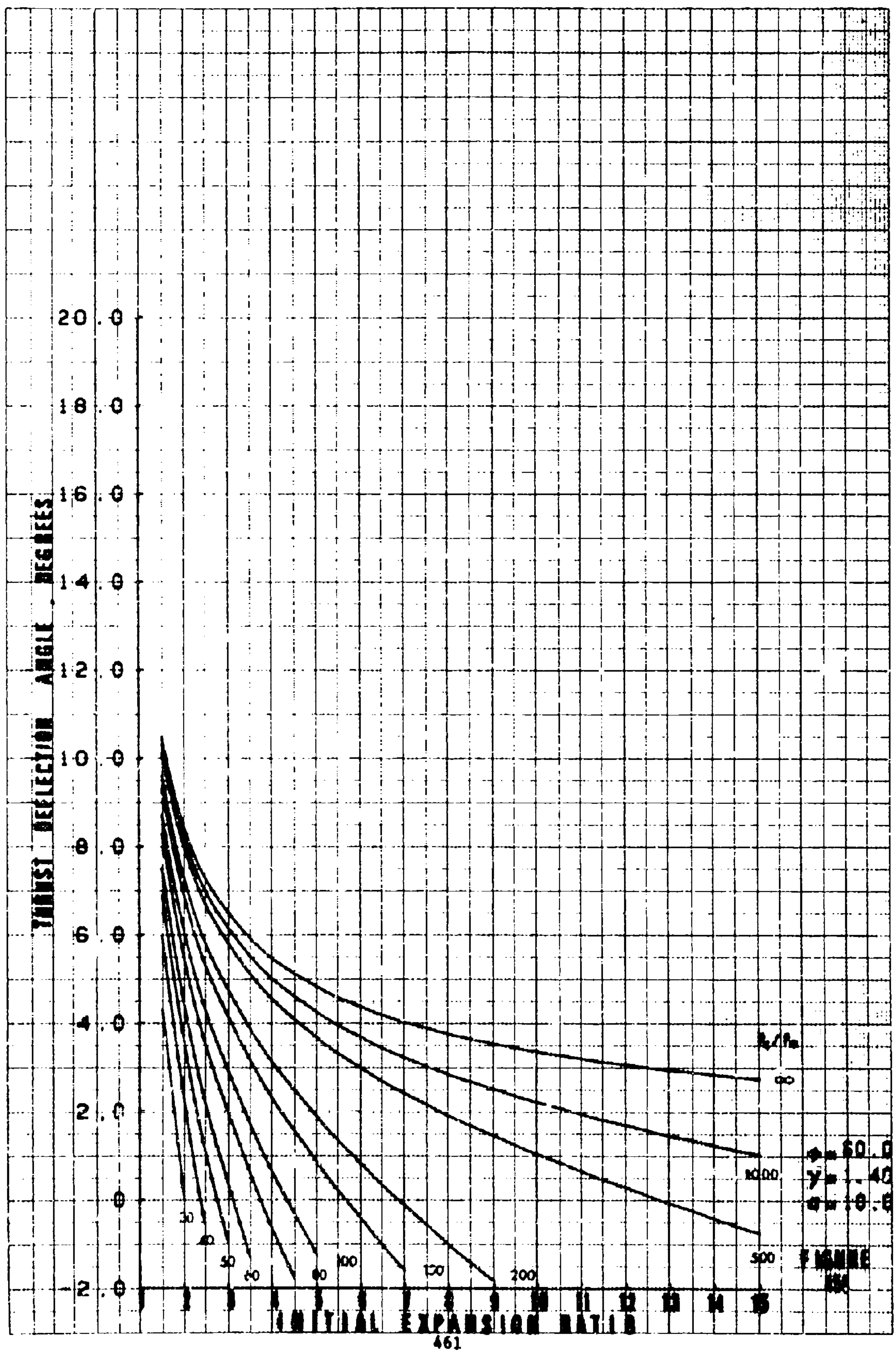
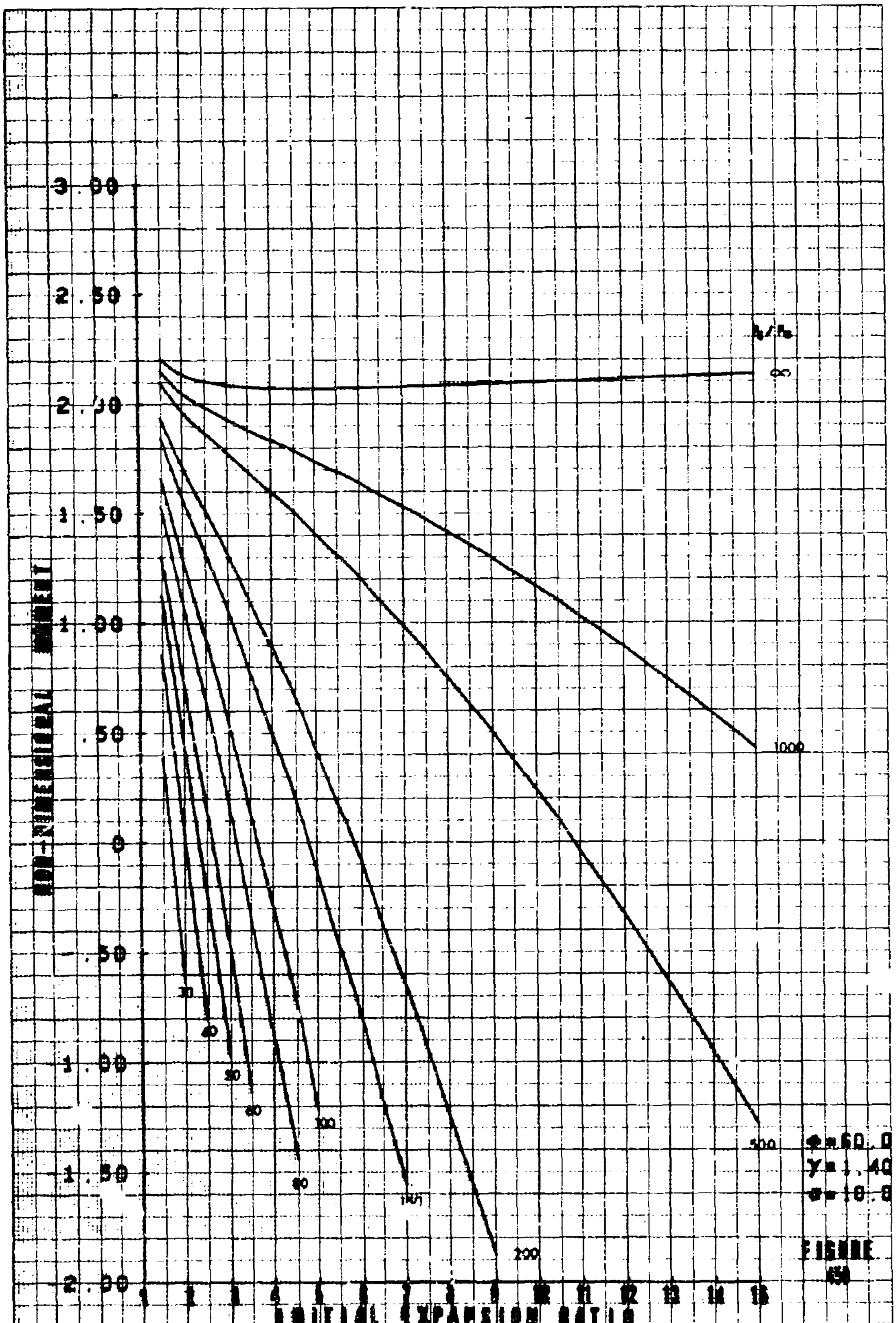
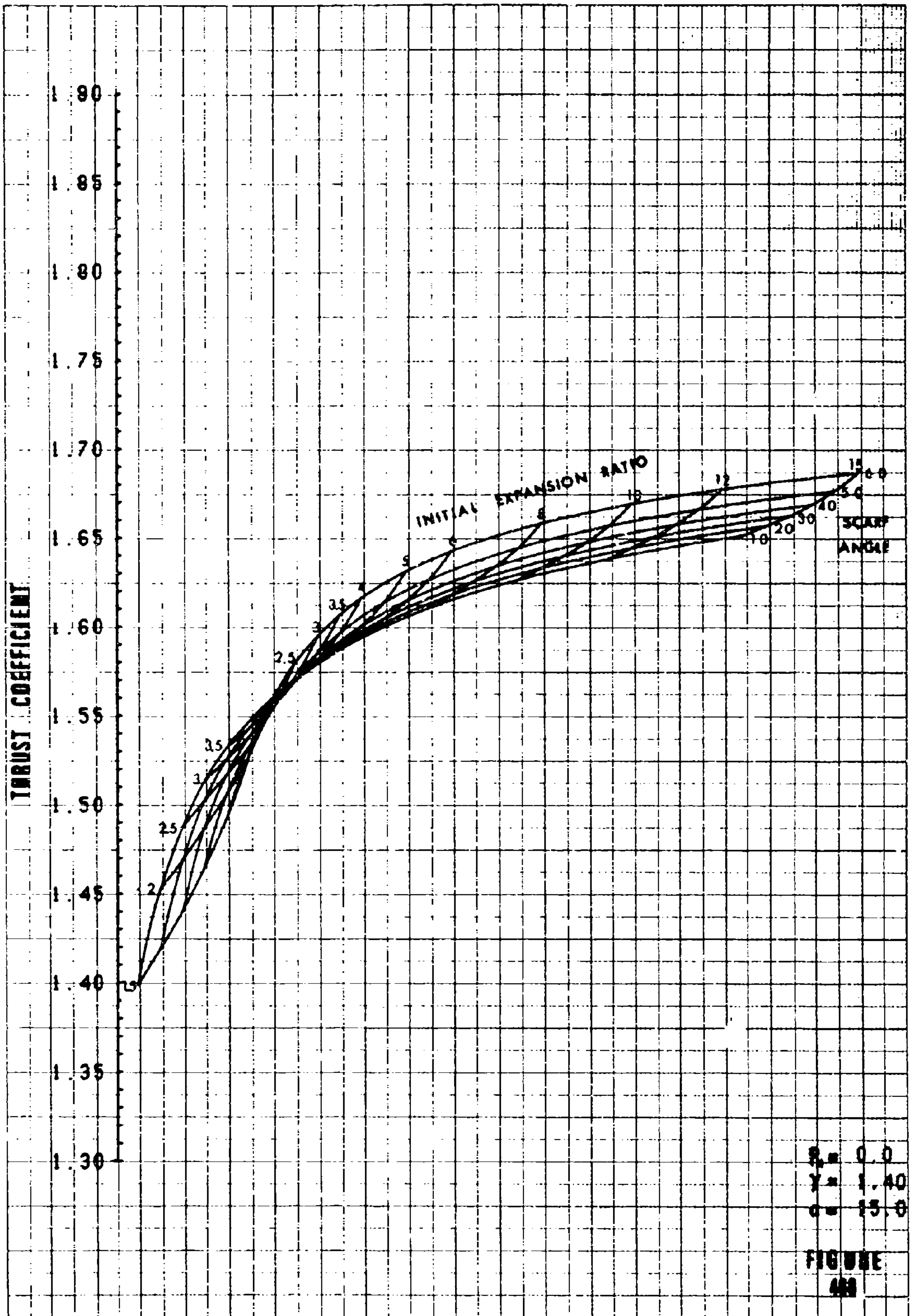

1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
THRUST COEFFICIENT
INITIAL EXPANSION RATIO
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
∞
1000
500
200
150
60
50
40
30
20
γ = 1.40
= 10.0

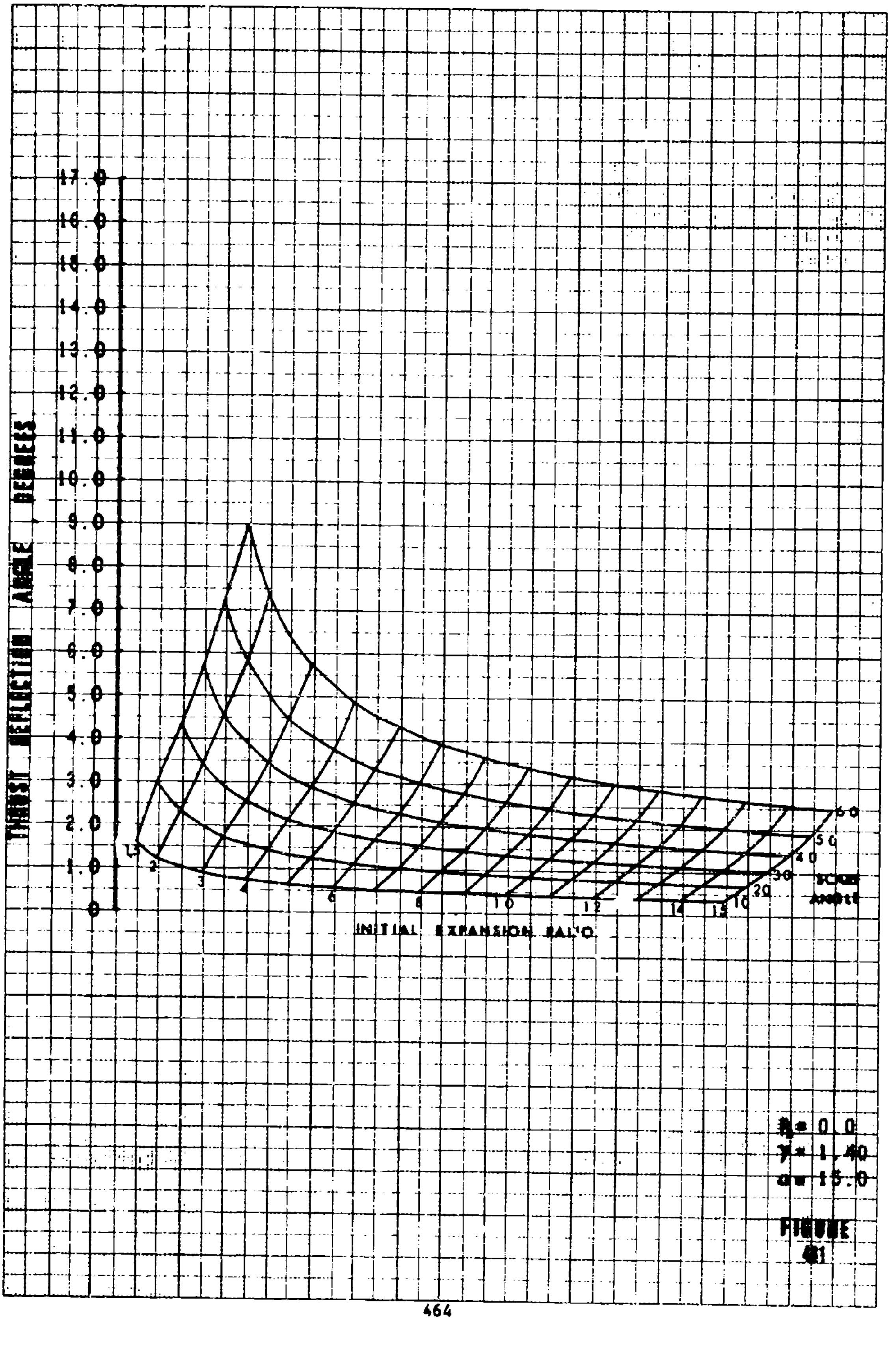
FIGURE 157


THRUST DEFLECTION ANGLE, DEGREES
20.0
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0
-2.0
INITIAL EXPANSION RATIO
30
40
50
60
80
100
150
200
500
1000
∞

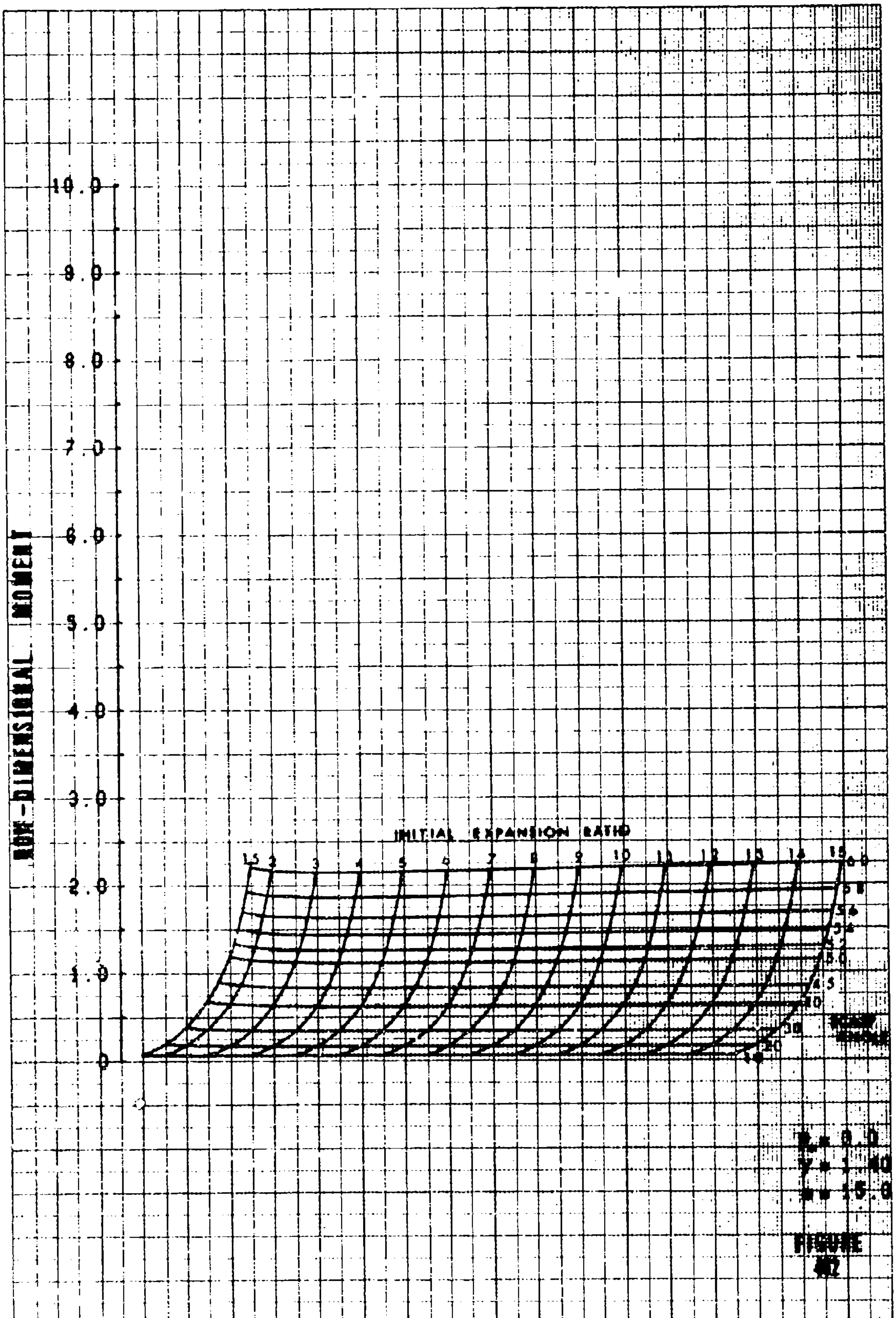


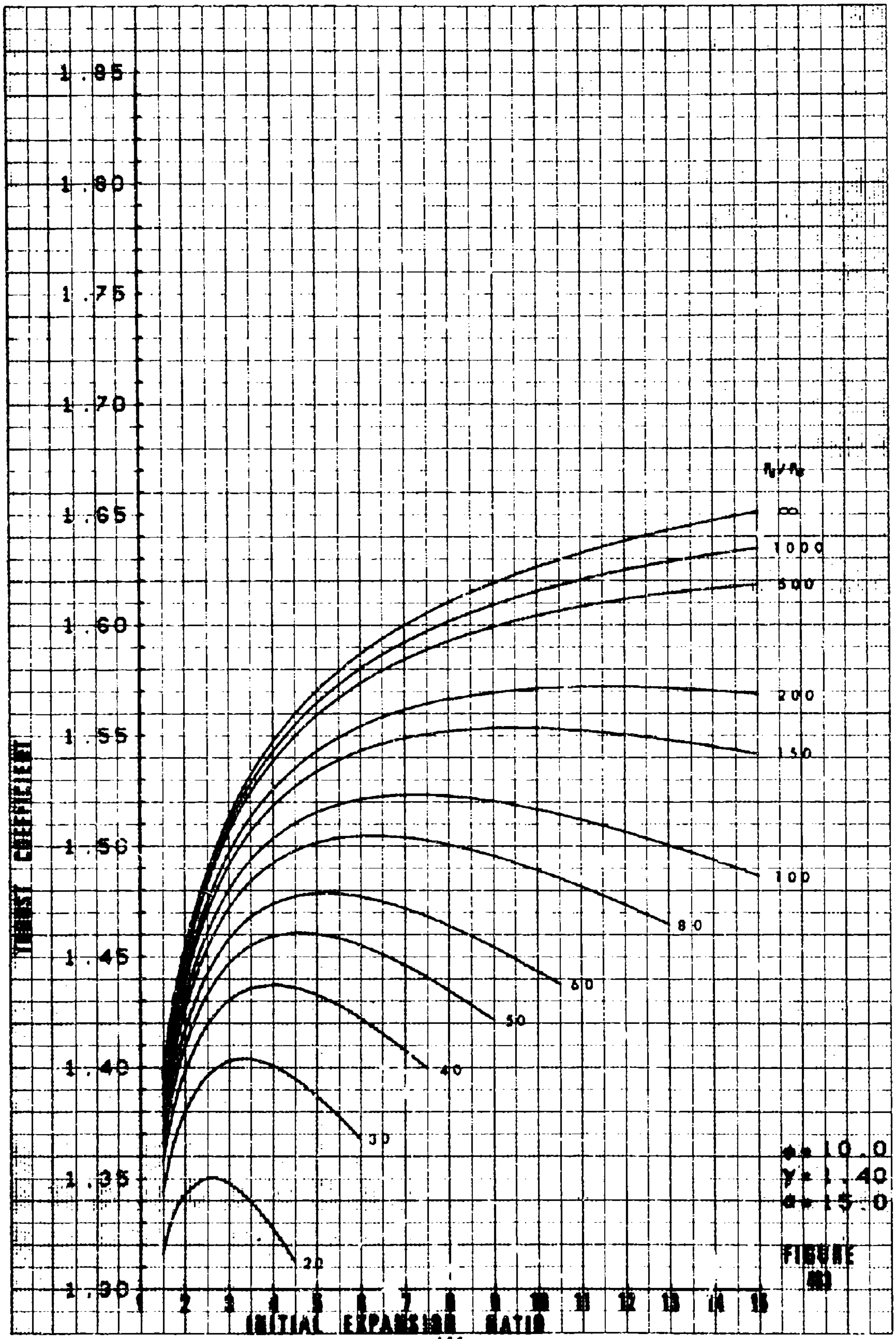
3.00
2.50
2.00
1.50
1.00
.50
0
-.50
-1.00
-1.50
-2.00
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
∞
1000
500
200
150
100
80
60
50
40
30


THRUST COEFFICIENT
1.90
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
INITIAL EXPANSION RATIO
SCARF ANGLE
10
20
30
40
50
60
γ = 1.40
= 15.0
FIGURE

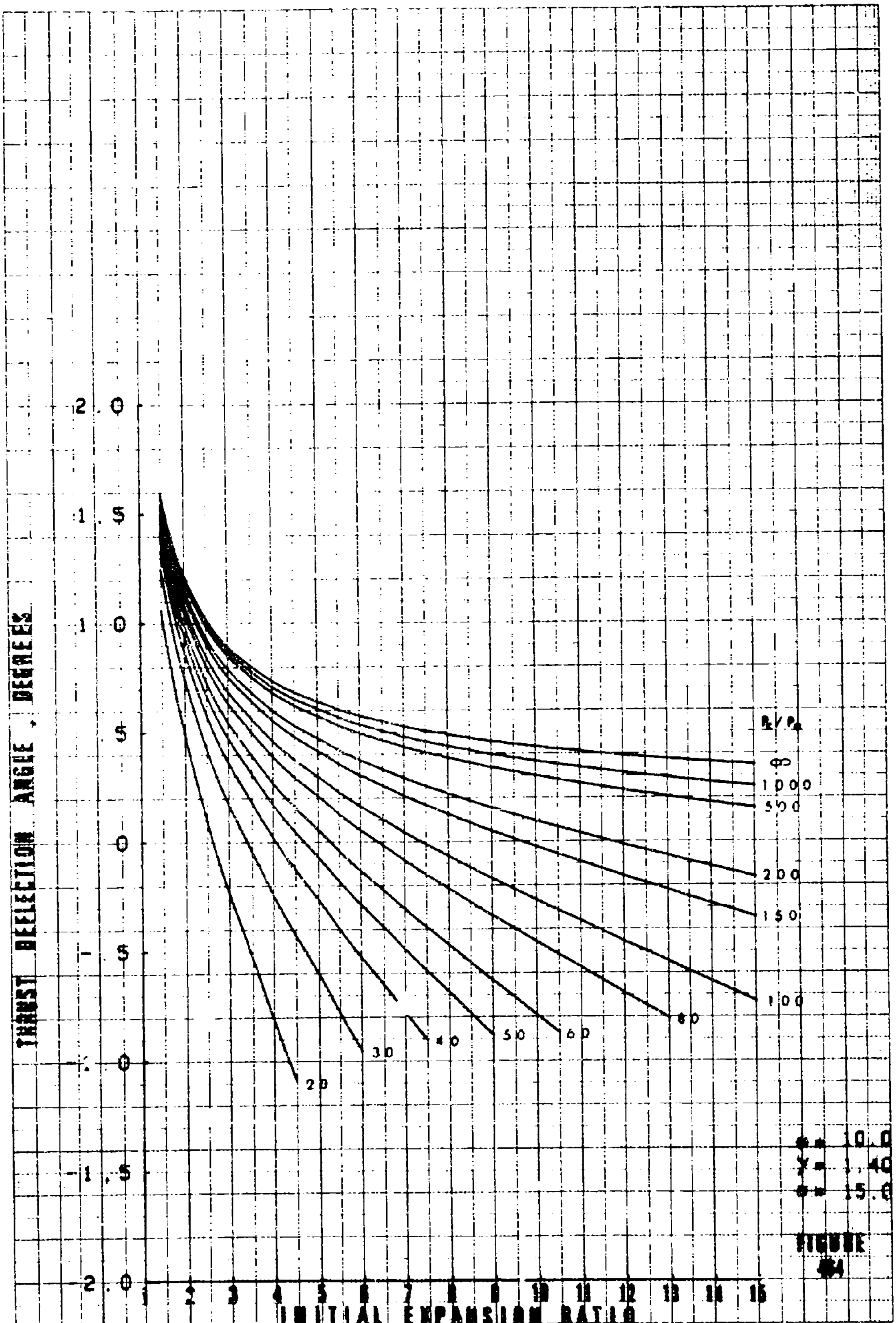


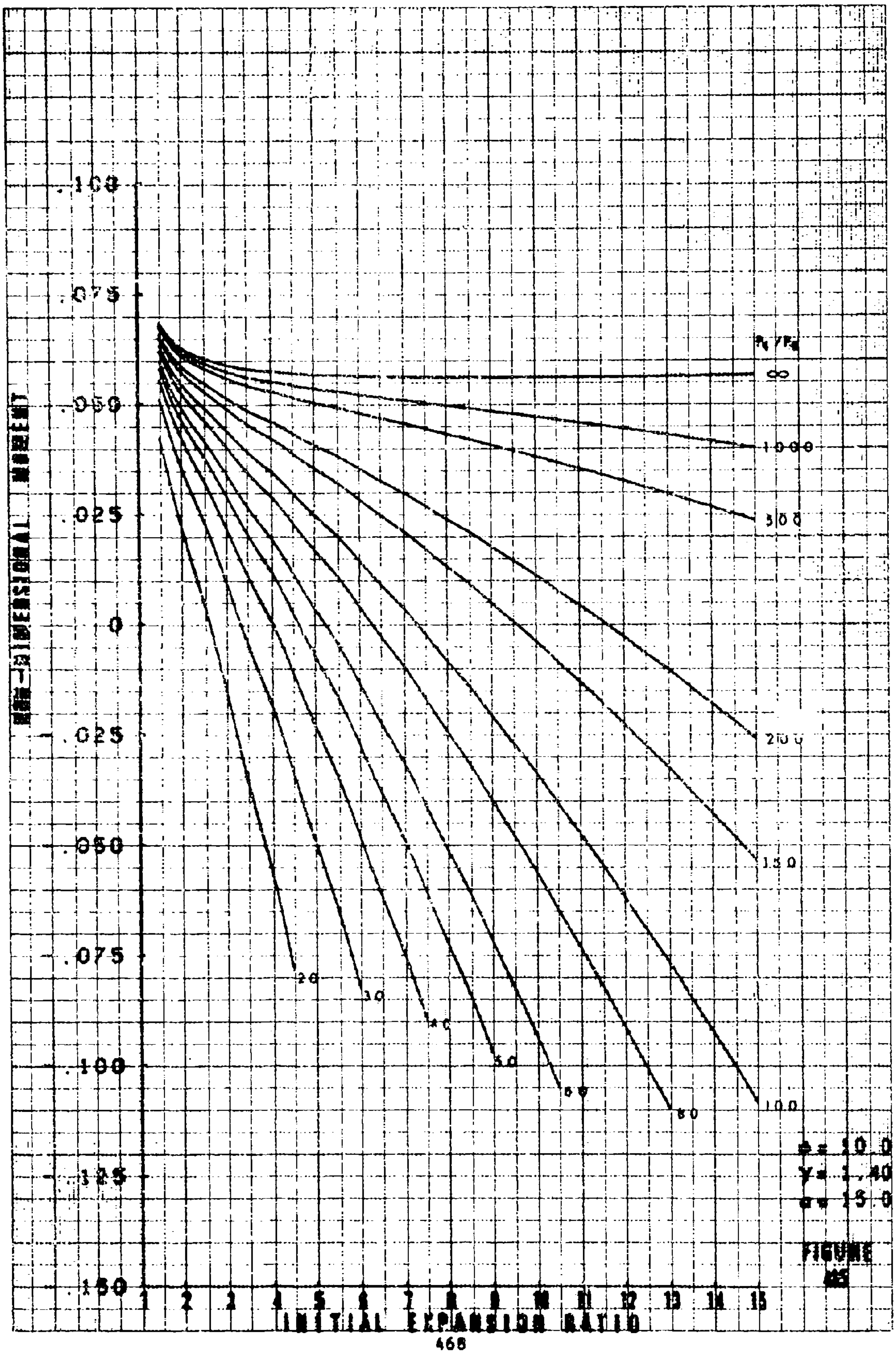
THRUST DEFLECTION ANGLE, DEGREES
17.0
16.0
15.0
14.0
13.0
12.0
11.0
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
1.5
2
3
4
6
8
10
12
14
15
10
20
30
40
50
60
SCARF ANGLE
INITIAL EXPANSION RATIO
= 0.0
γ = 1.40
α = 15.0
FIGURE 41

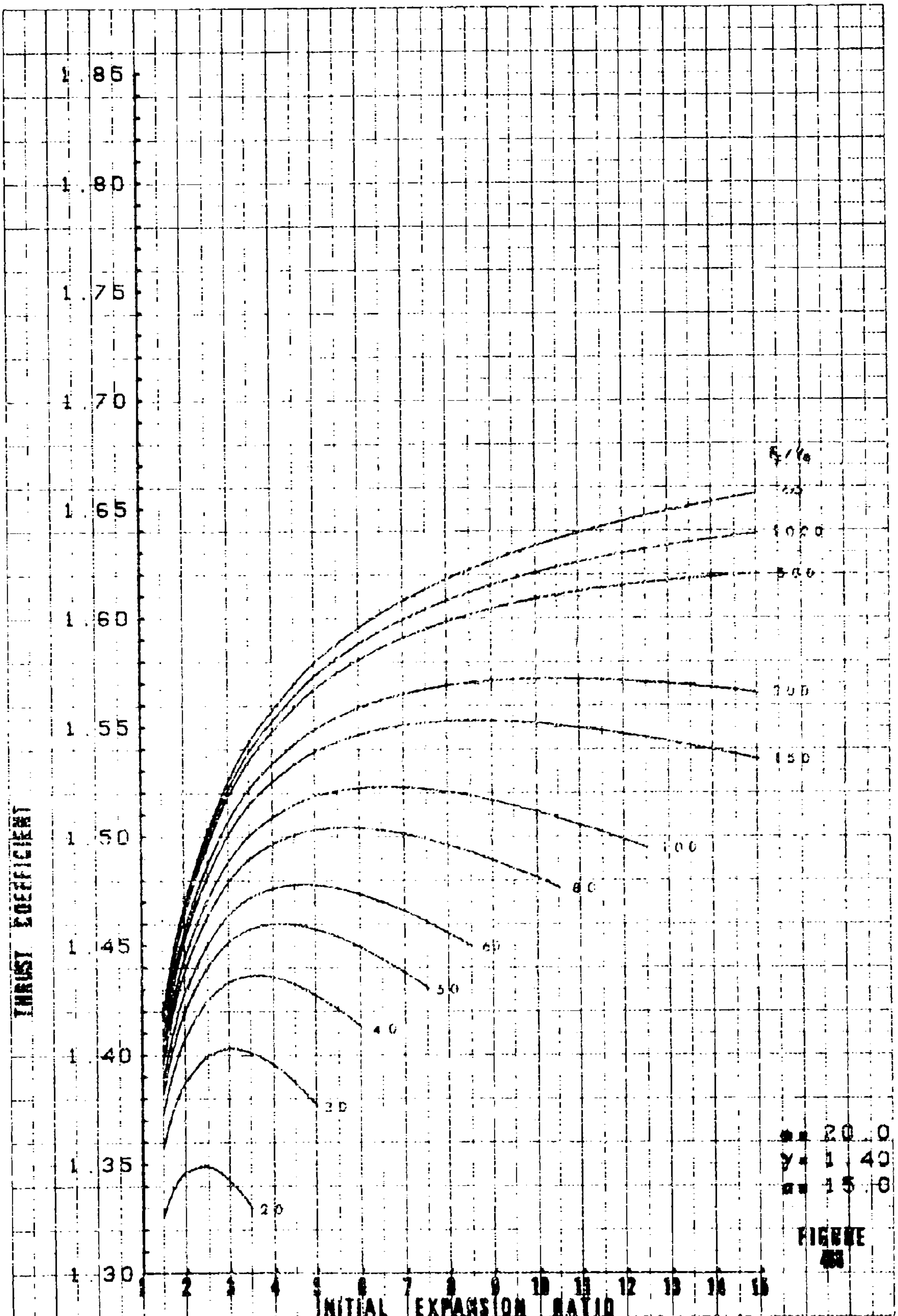

NON-DIMENSIONAL MOMENT
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
INITIAL EXPANSION RATIO
1.5
2
3
4
5
6
7
8
9
10
11
12
13
14
15
FIGURE



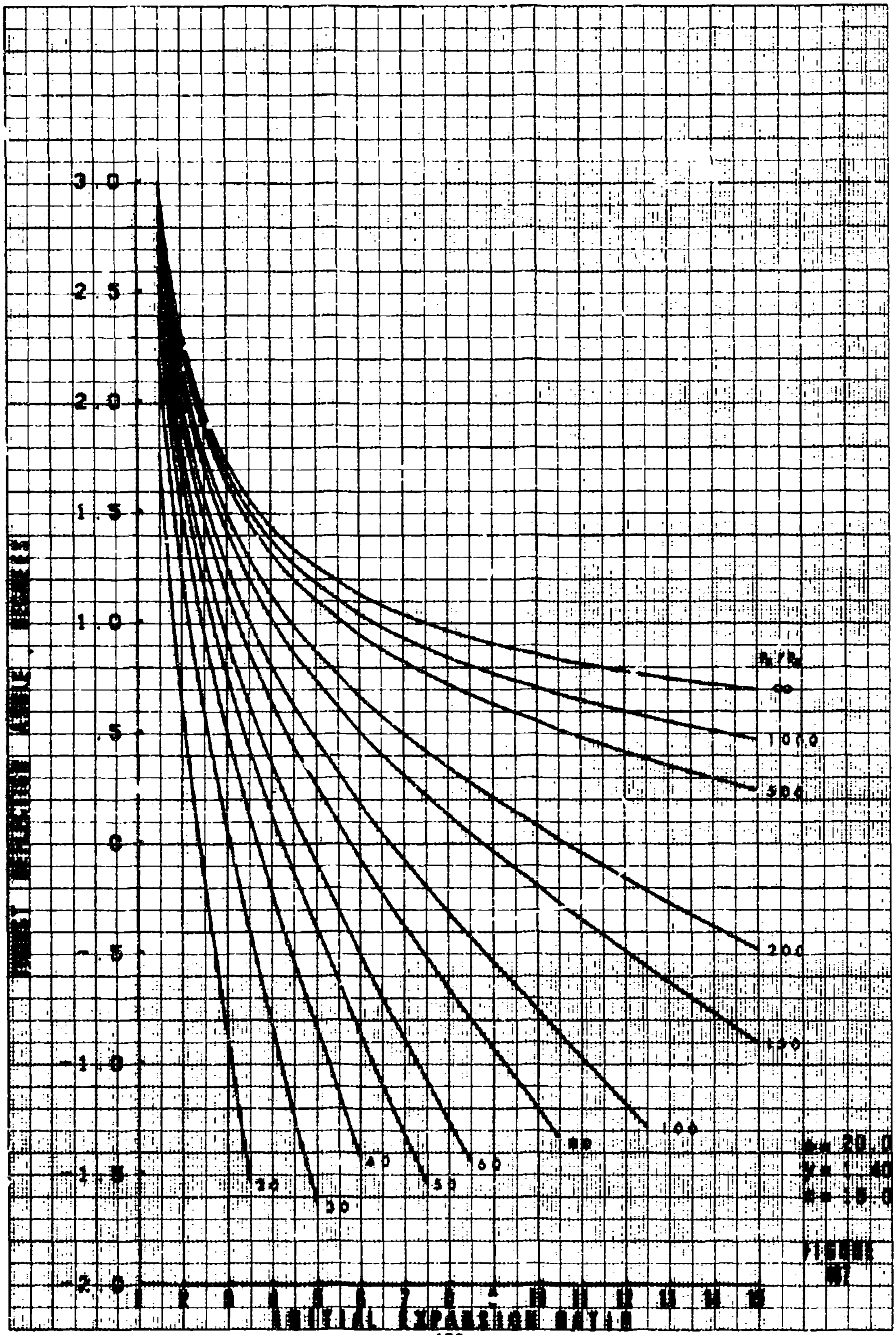
THRUST COEFFICIENT
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
P_0/P_a
∞
1000
500
200
150
100
80
60
50
40
30
20
φ = 10.0
γ = 1.40
α = 15.0
FIGURE
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO

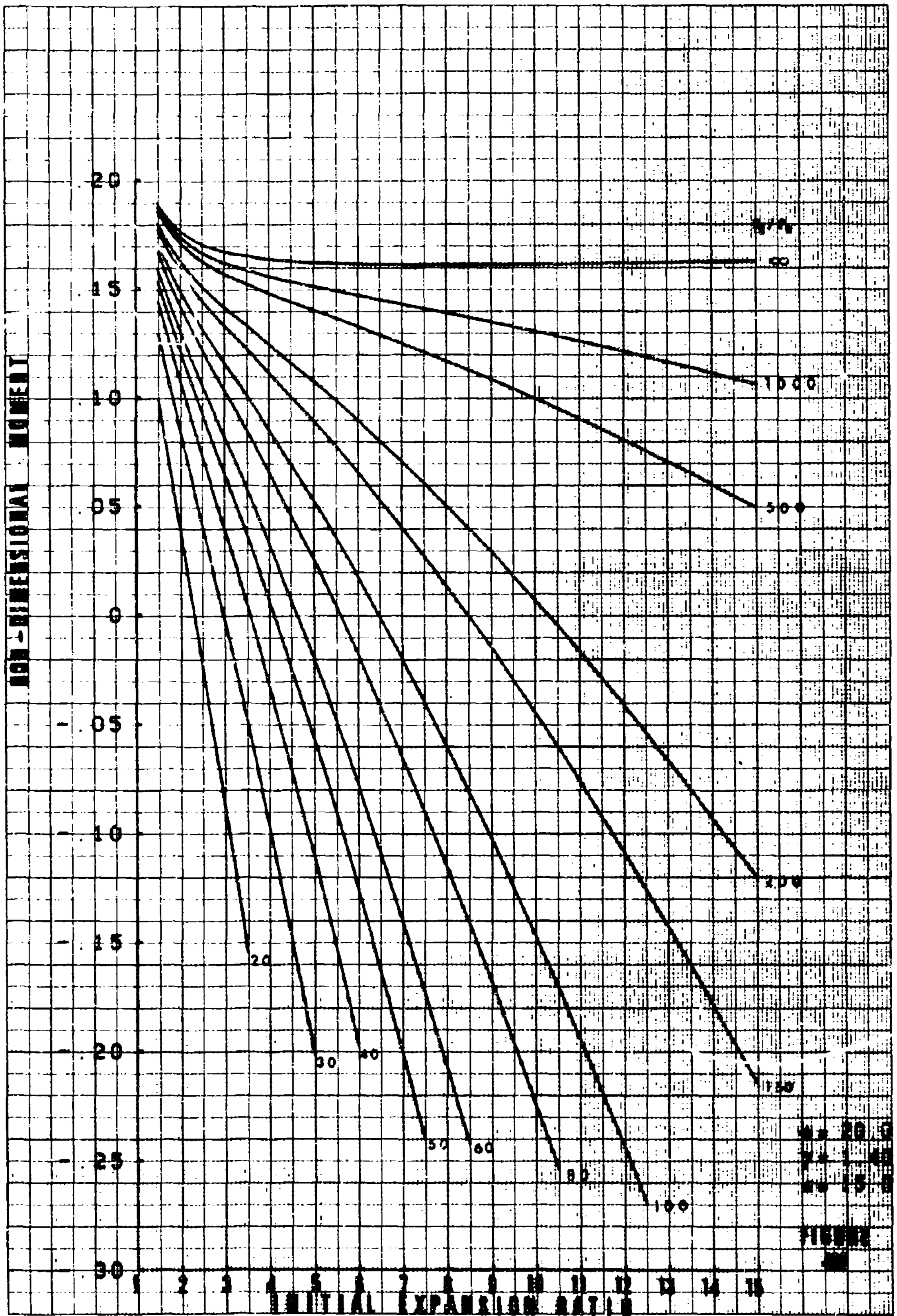

THRUST DEFLECTION ANGLE, DEGREES
2.0
1.5
1.0
.5
0
-.5
-1.0
-1.5
-2.0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
∞
1000
500
200
150
100
80
60
50
40
30
20
10.0
1.40
15.0
FIGURE

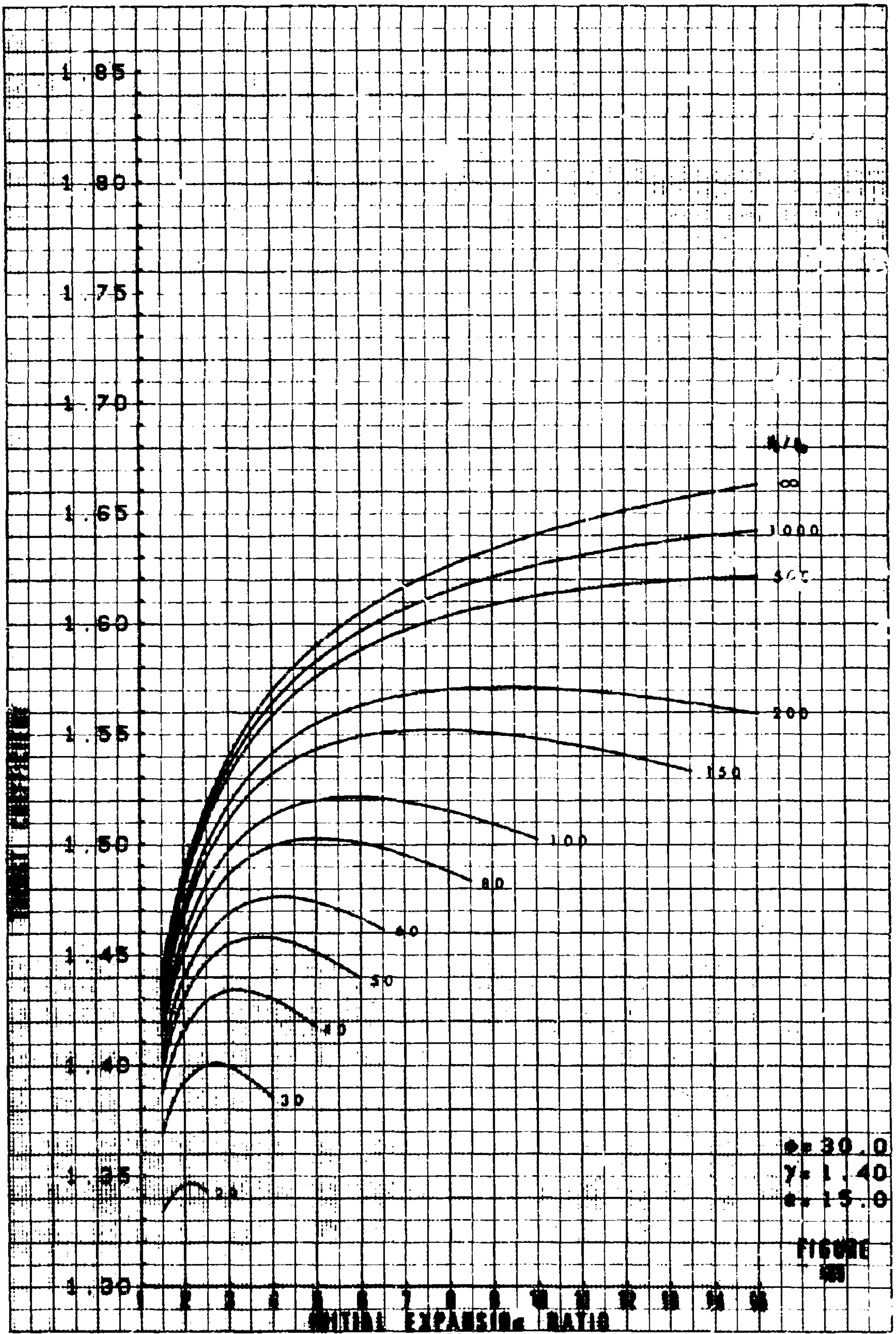

NON-DIMENSIONAL MOMENT
.100
.075
.050
.025
0
-.025
-.050
-.075
-.100
-.125
-.150
P_c/P_a
∞
1000
500
200
150
100
80
60
50
40
30
20
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
FIGURE

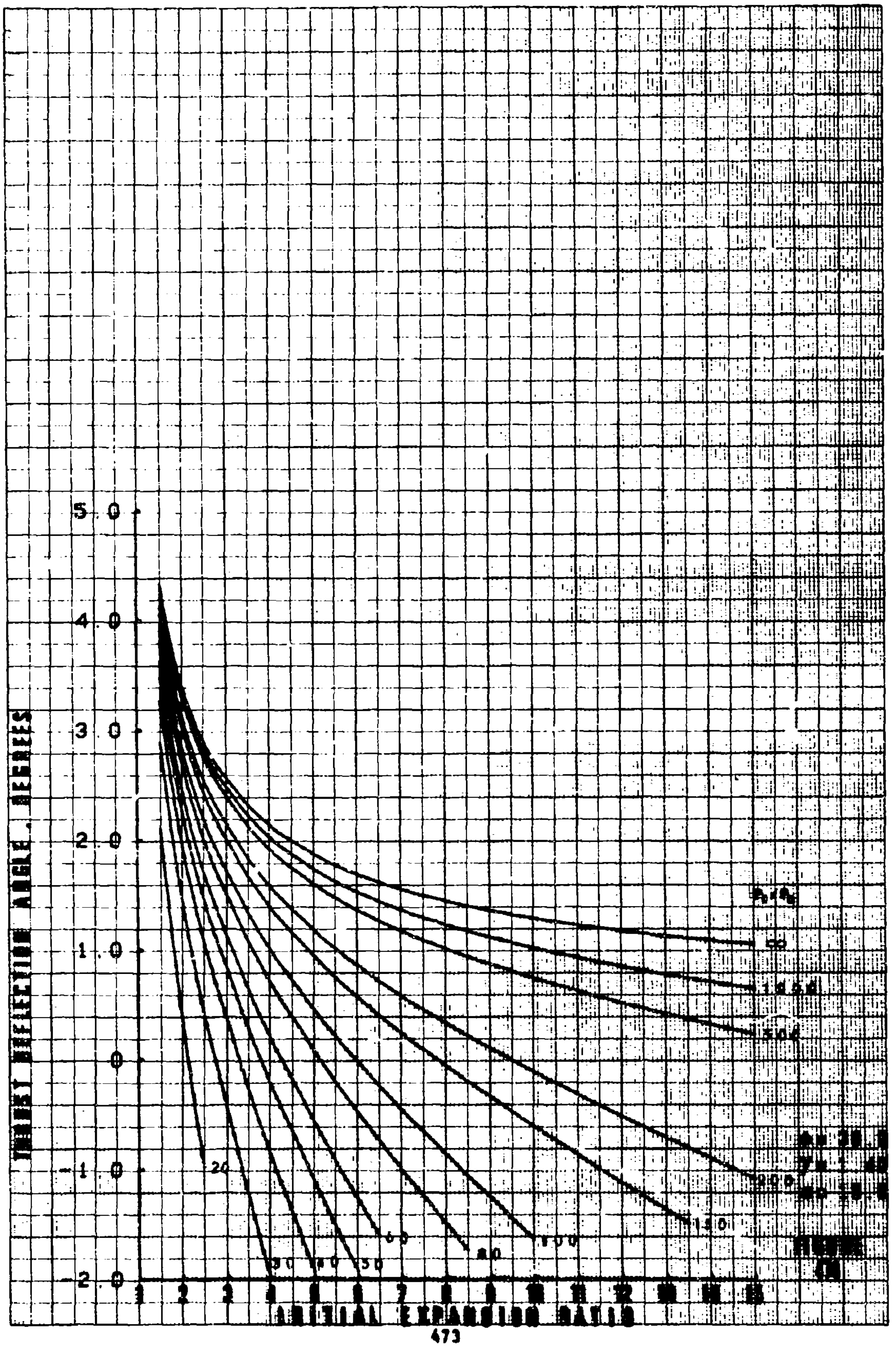


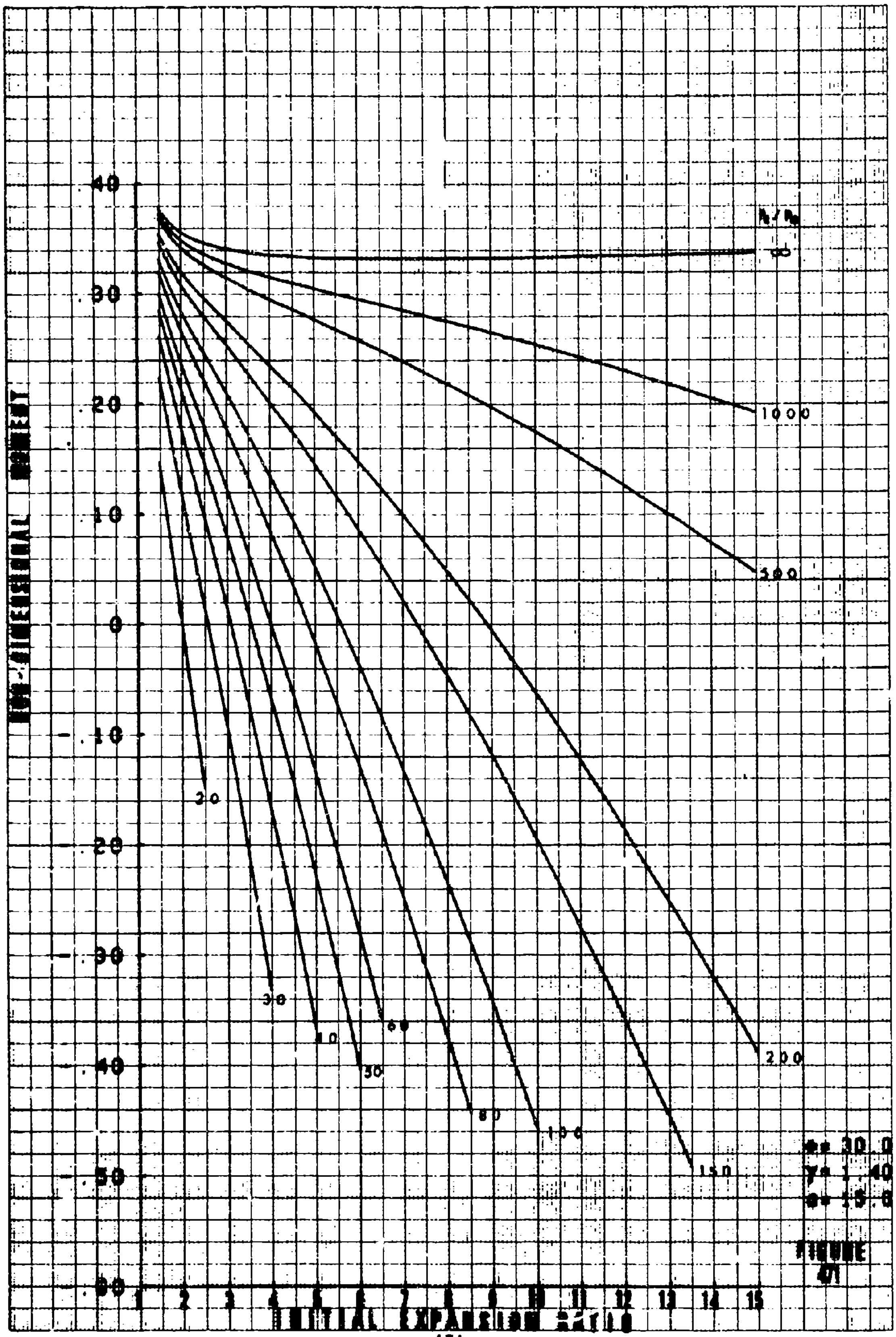
THRUST COEFFICIENT
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
INITIAL EXPANSION RATIO
1020
200
150
100
80
60
50
40
30
20
20.0
1.40
15.0
FIGURE

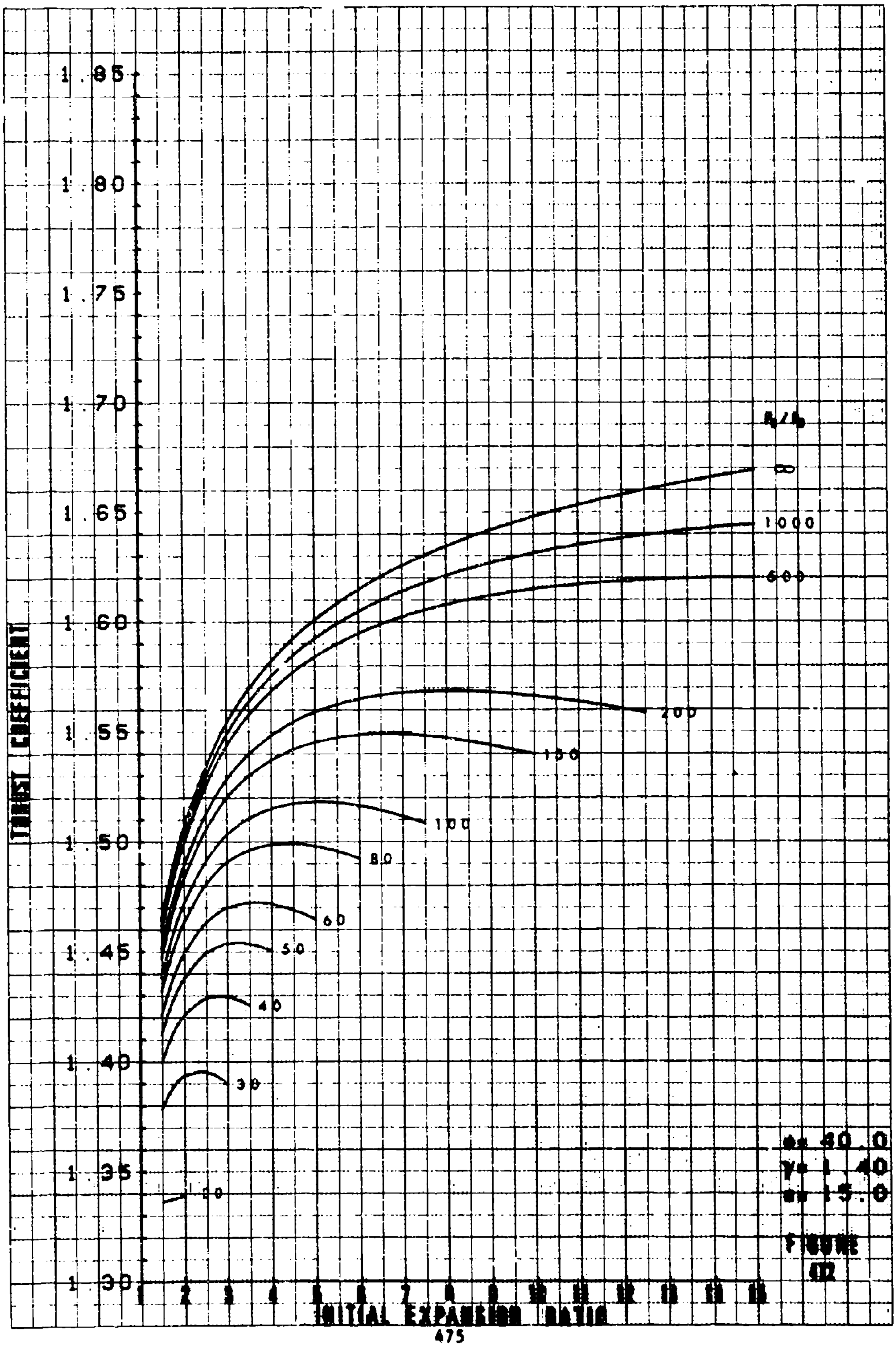

3.0
2.5
2.0
1.5
1.0
.5
0
-.5
-1.0
-2.0
∞
1000
500
200
150
100
80
60
50
40
30
20
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15

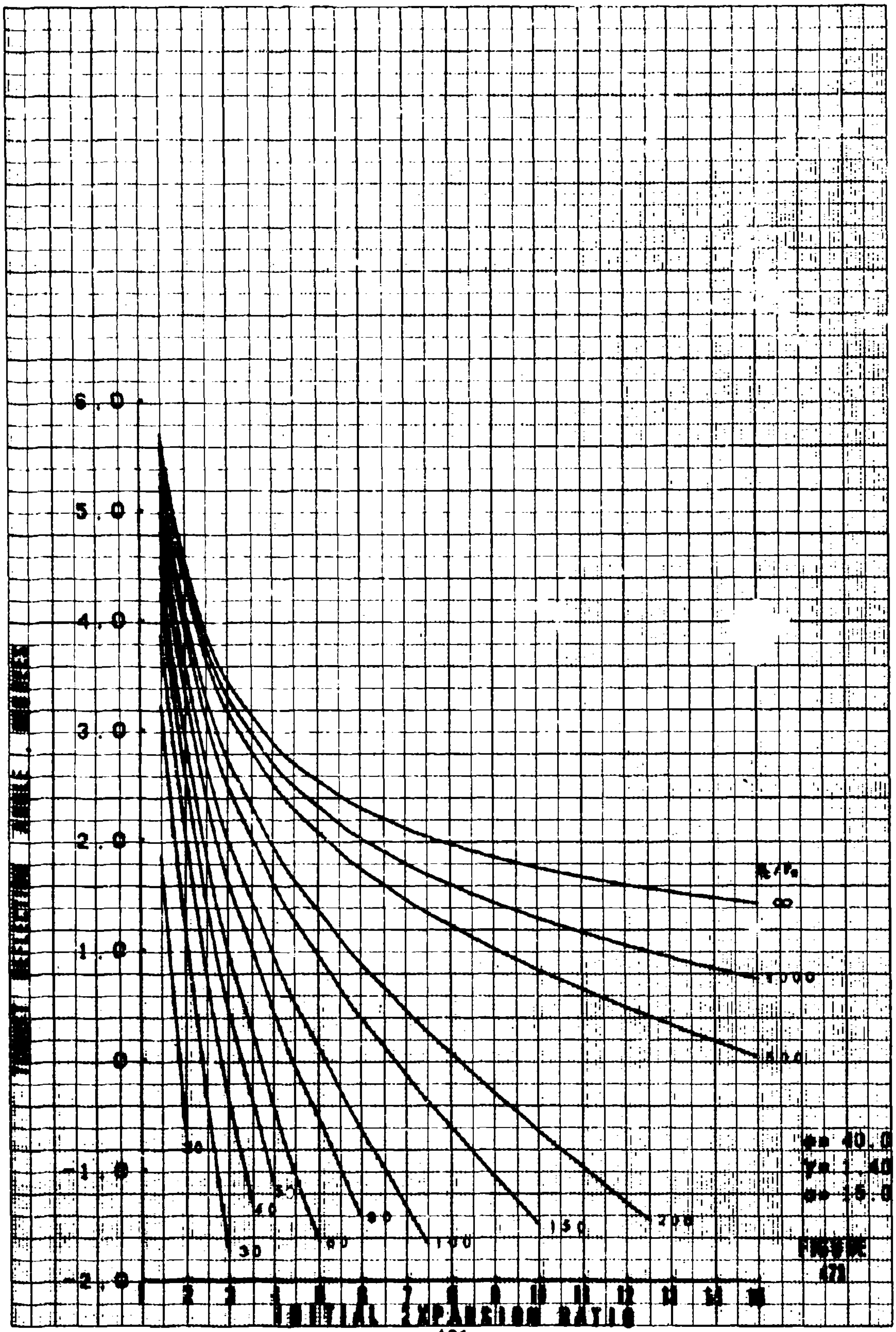

NON-DIMENSIONAL MOMENT
20
15
10
05
0
-.05
-.10
-.15
-.20
-.25
-.30
∞
1000
500
200
150
100
80
60
50
40
30
20
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
INITIAL EXPANSION RATIO

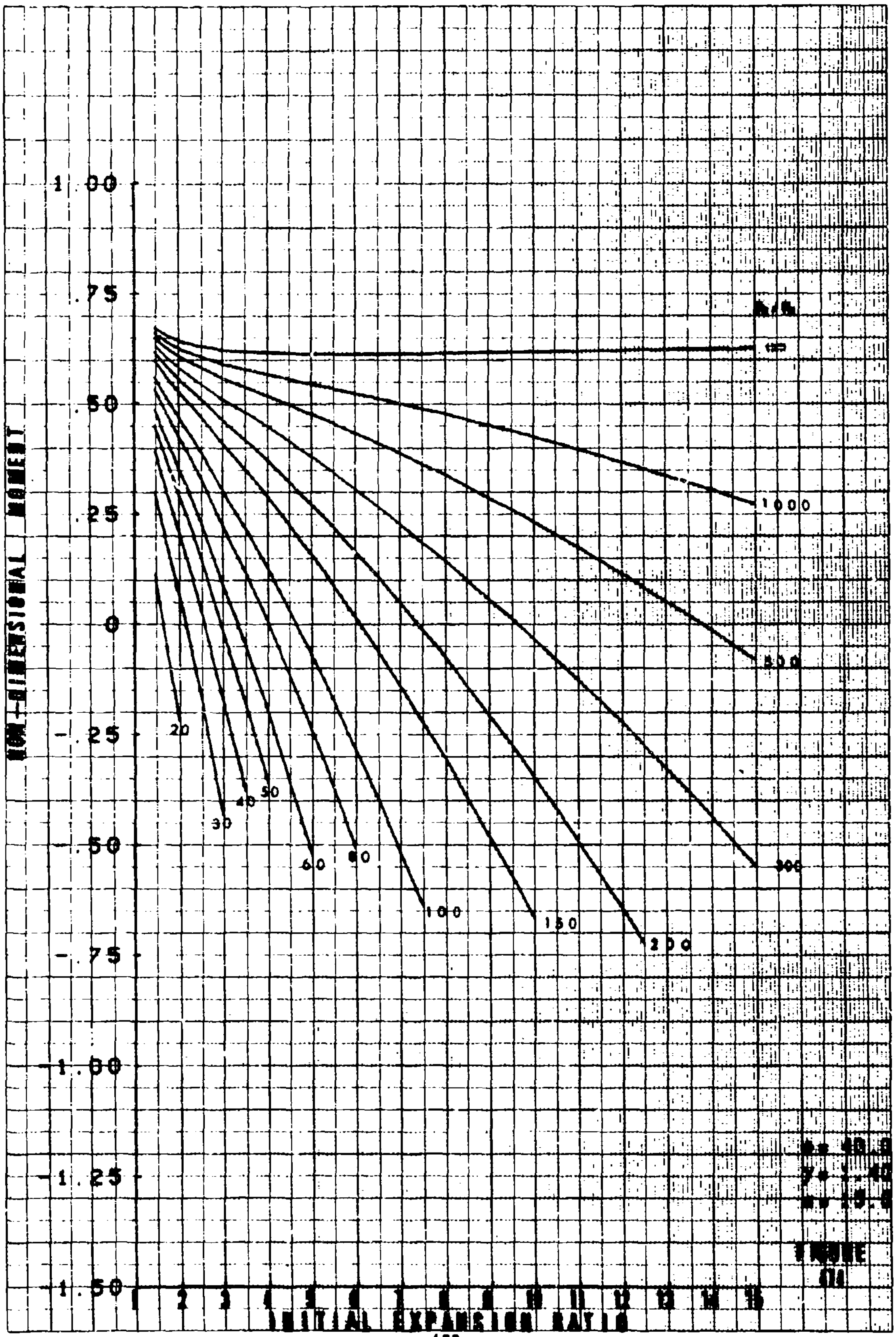

1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
∞
1000
200
150
100
80
60
50
40
30
20
γ= 1.40
FIGURE


THRUST DEFLECTION ANGLE, DEGREES
5.0
4.0
3.0
2.0
1.0
0
-1.0
-2.0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
20
30
40
50
60
80
100
150
200
500
1000
∞

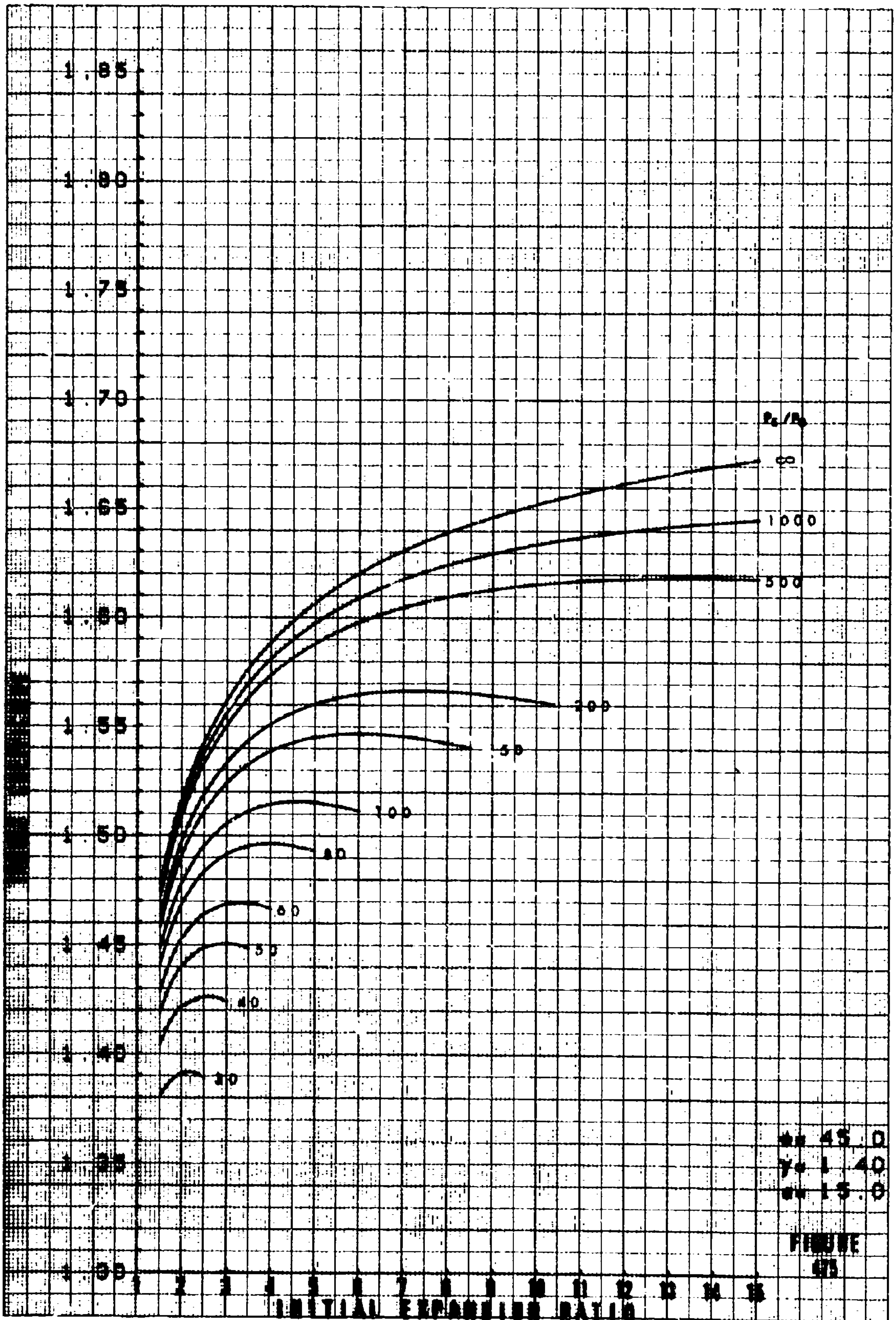

40
30
20
10
0
-10
-20
-30
-40
-50
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
∞
1000
500
200
150
100
80
60
50
40
30
20


1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
THRUST COEFFICIENT
1000
600
200
150
100
80
60
50
40
30
20
INITIAL EXPANSION RATIO

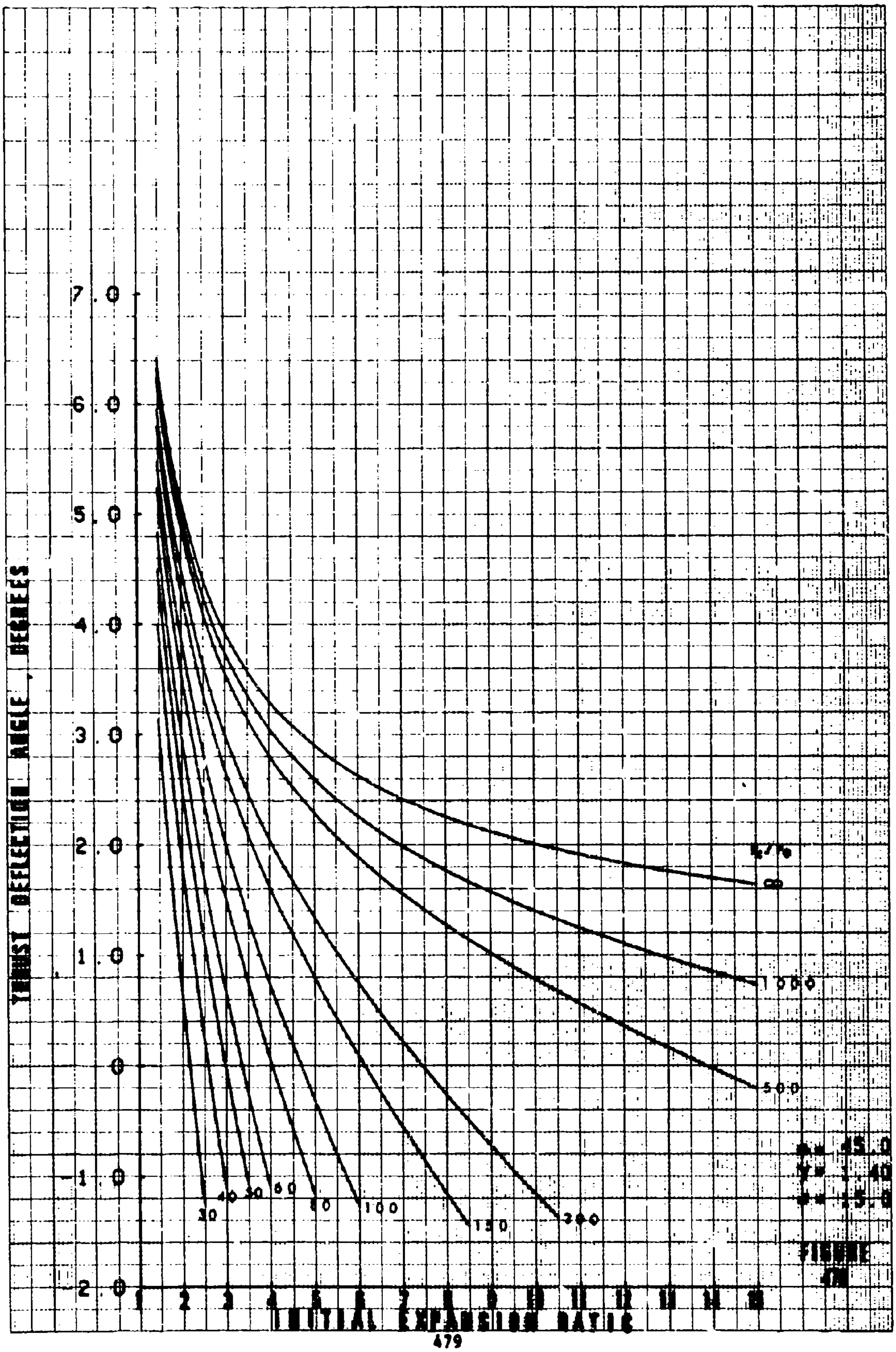

6.0
5.0
4.0
3.0
2.0
1.0
0
-1.0
-2.0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
∞
20
30
40
50
60
80
100
150
200

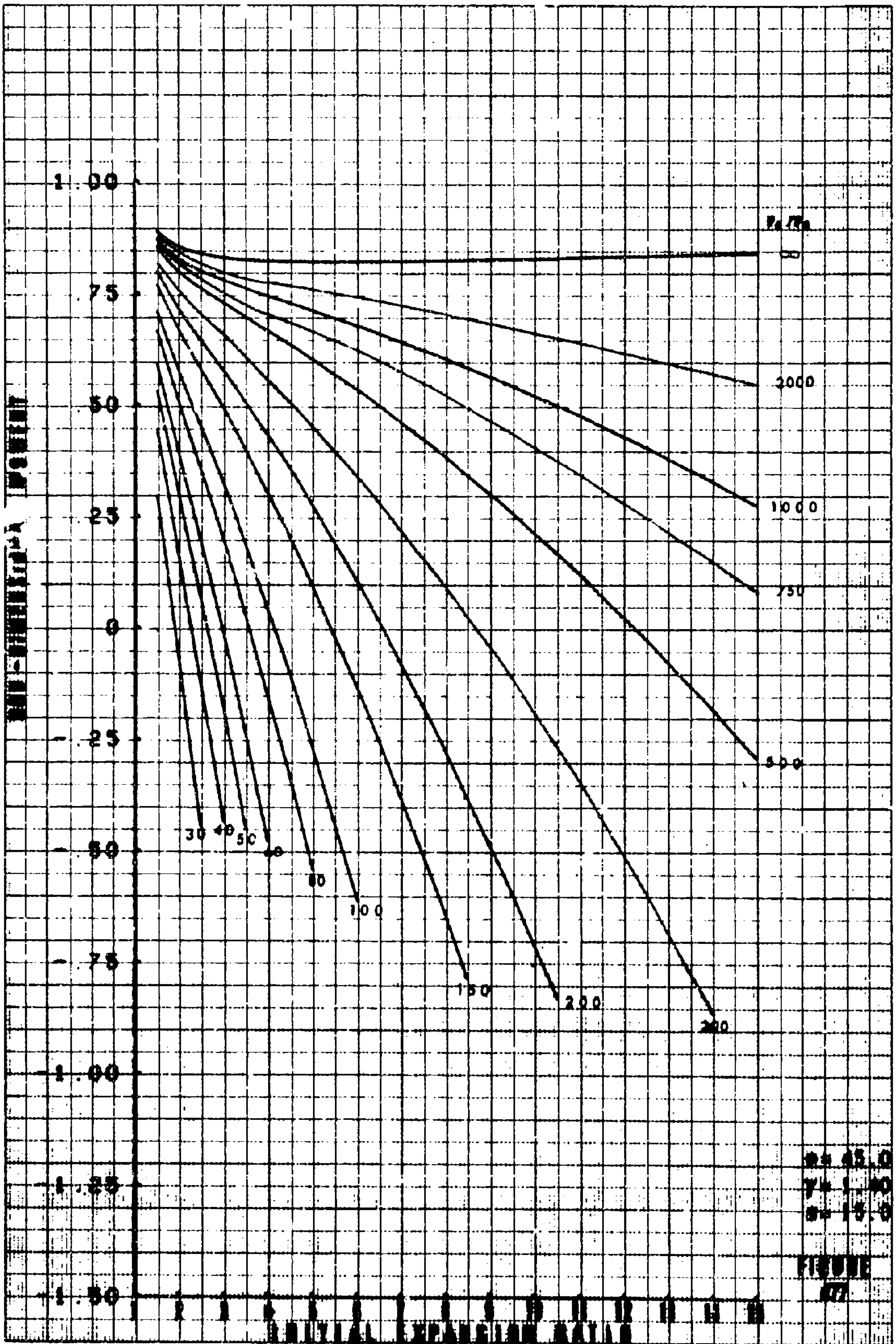


NON-DIMENSIONAL MOMENT
1.00
.75
.50
.25
0
-.25
-.50
-.75
-1.00
-1.25
-1.50
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
INITIAL EXPANSION RATIO
∞
1000
500
300
200
150
100
80
60
50
40
30
20

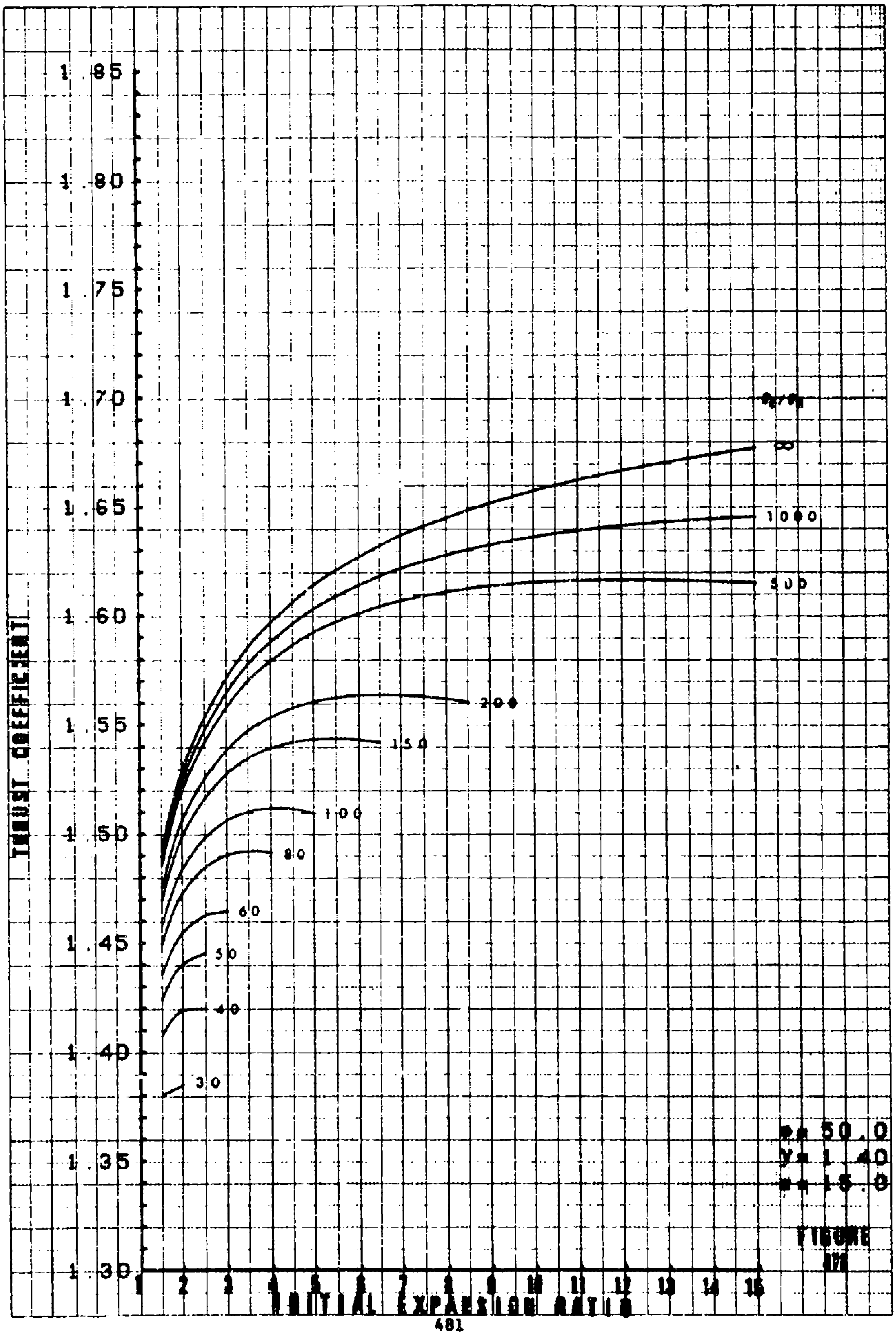


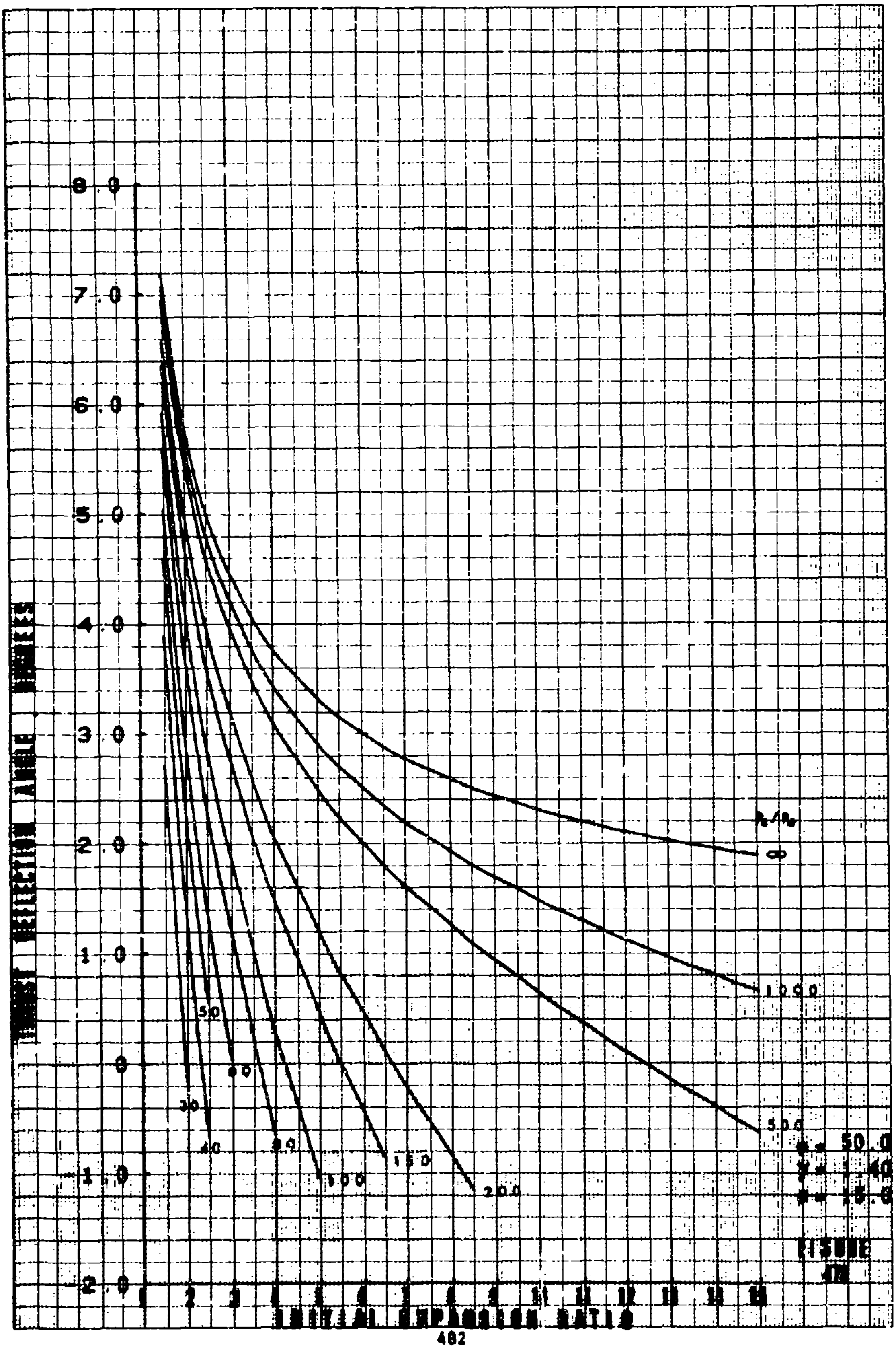
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
∞
1000
500
200
150
100
80
60
50
40
30
45.0
1.40
15.0
FIGURE
475

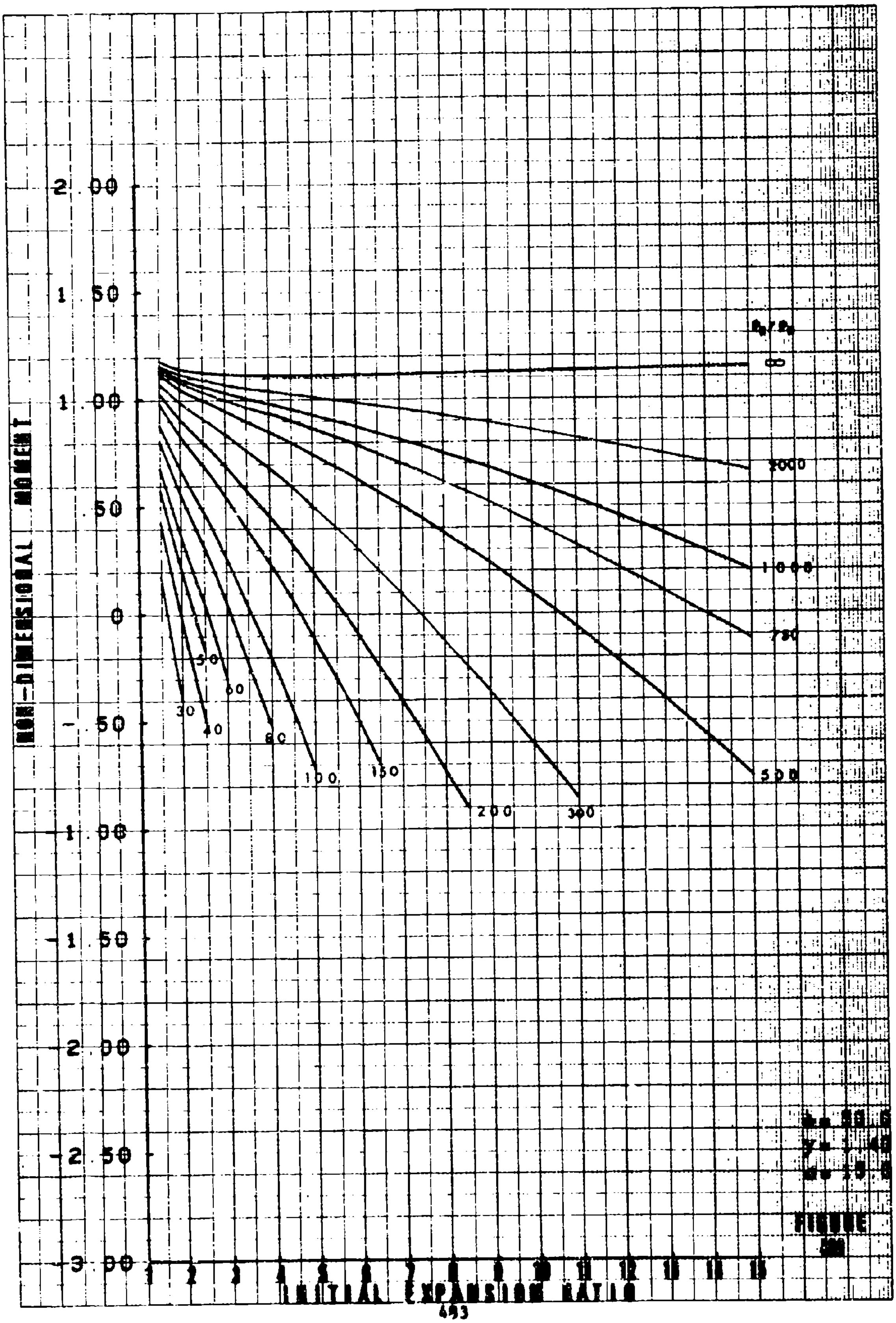

THRUST DEFLECTION ANGLE, DEGREES
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
-1.0
-2.0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
INITIAL EXPANSION RATIO
∞
1000
500
200
150
100
80
60
50
40
30
45.0
1.40
15.0
FIGURE

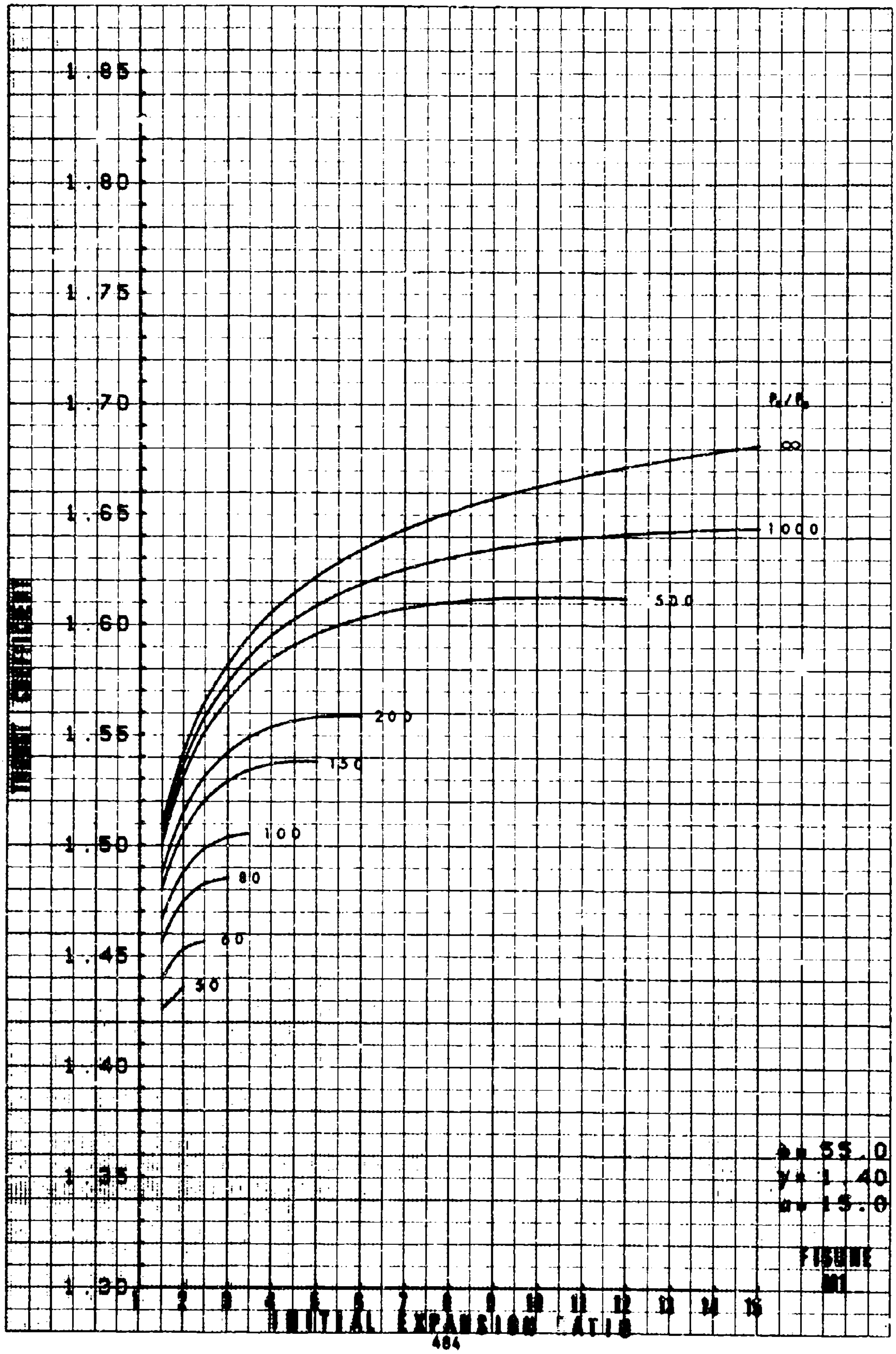


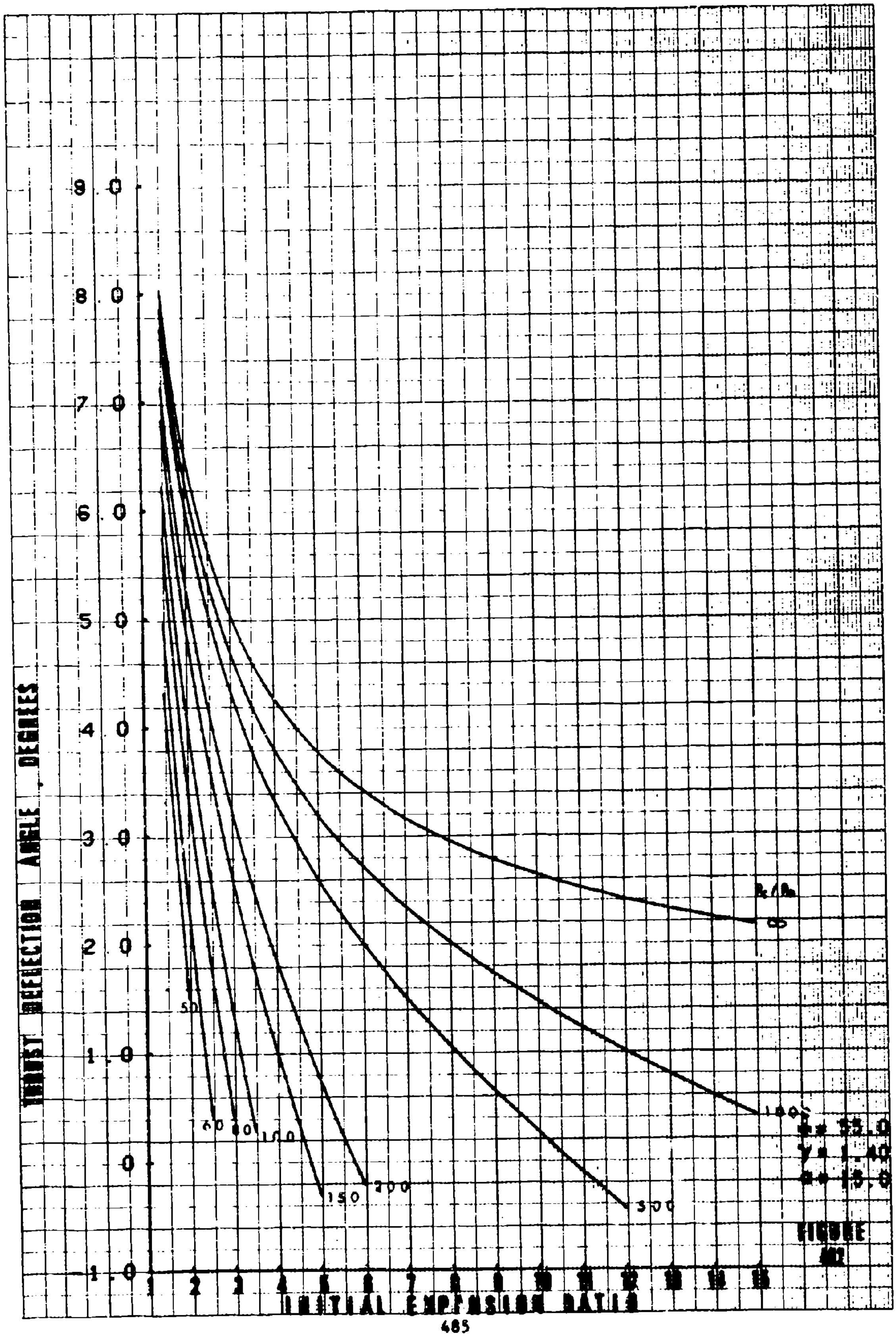
1.00
.75
.50
.25
0
-.25
-.50
-.75
-1.00
-1.25
-1.50
∞
2000
1000
750
500
300
200
150
100
80
50
40
30
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15

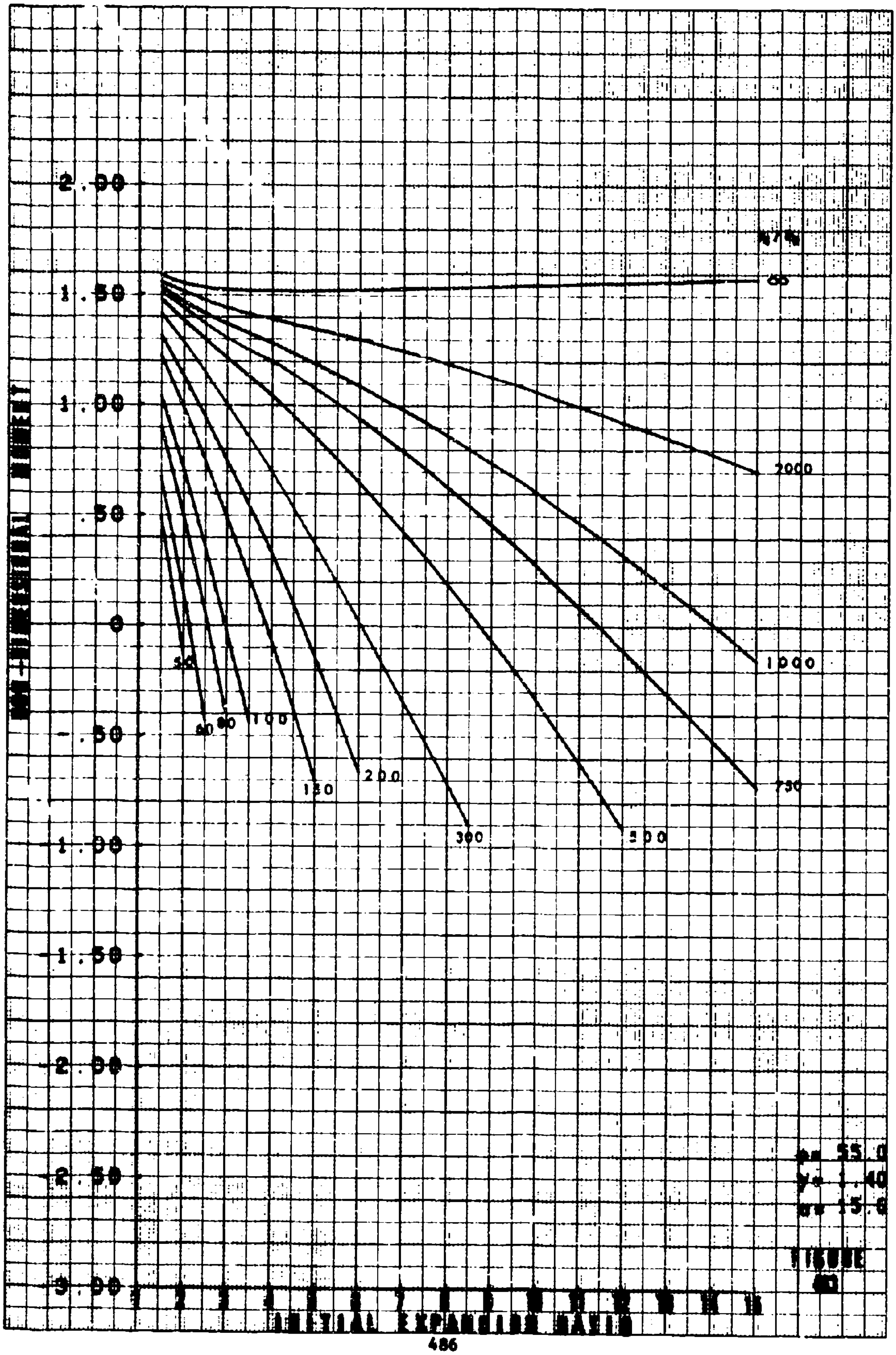

THRUST COEFFICIENT
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
INITIAL EXPANSION RATIO
∞
1000
500
200
150
100
80
60
50
40
30
50.0
γ= 1.40
15.0
FIGURE

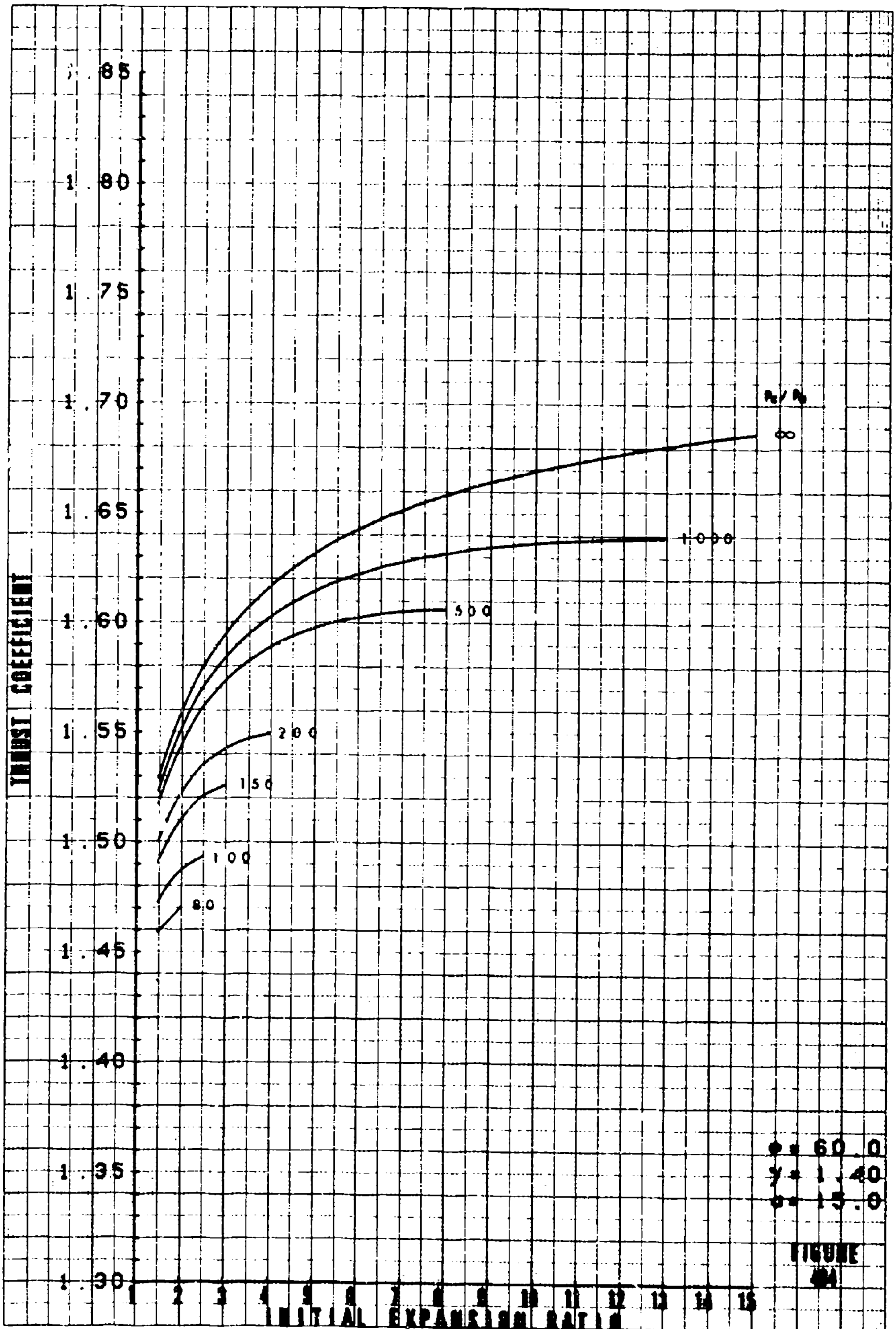

8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
1.0
2.0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
30
40
50
60
80
100
150
200
500
1000
∞
50.0
40
15.0

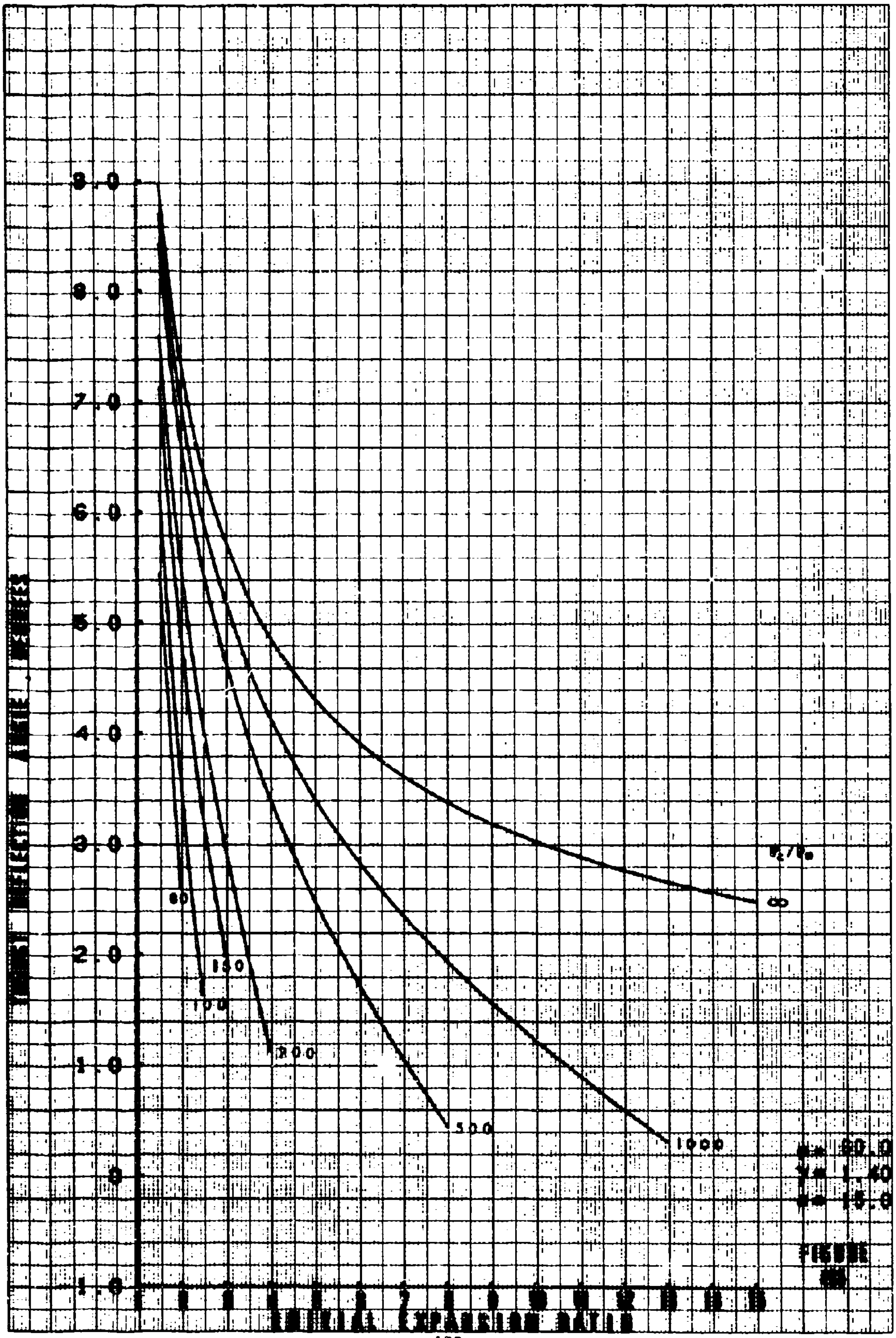

2.00
1.50
1.00
.50
0
-.50
-1.00
-1.50
-2.00
-2.50
-3.00
NON-DIMENSIONAL MOMENT
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
INITIAL EXPANSION RATIO
∞
2000
1000
750
500
300
200
150
100
80
60
50
40
30
FIGURE


1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
THRUST COEFFICIENT
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
P_c/P_a
∞
1000
500
200
150
100
80
60
50
55.0
1.40
15.0
FIGURE

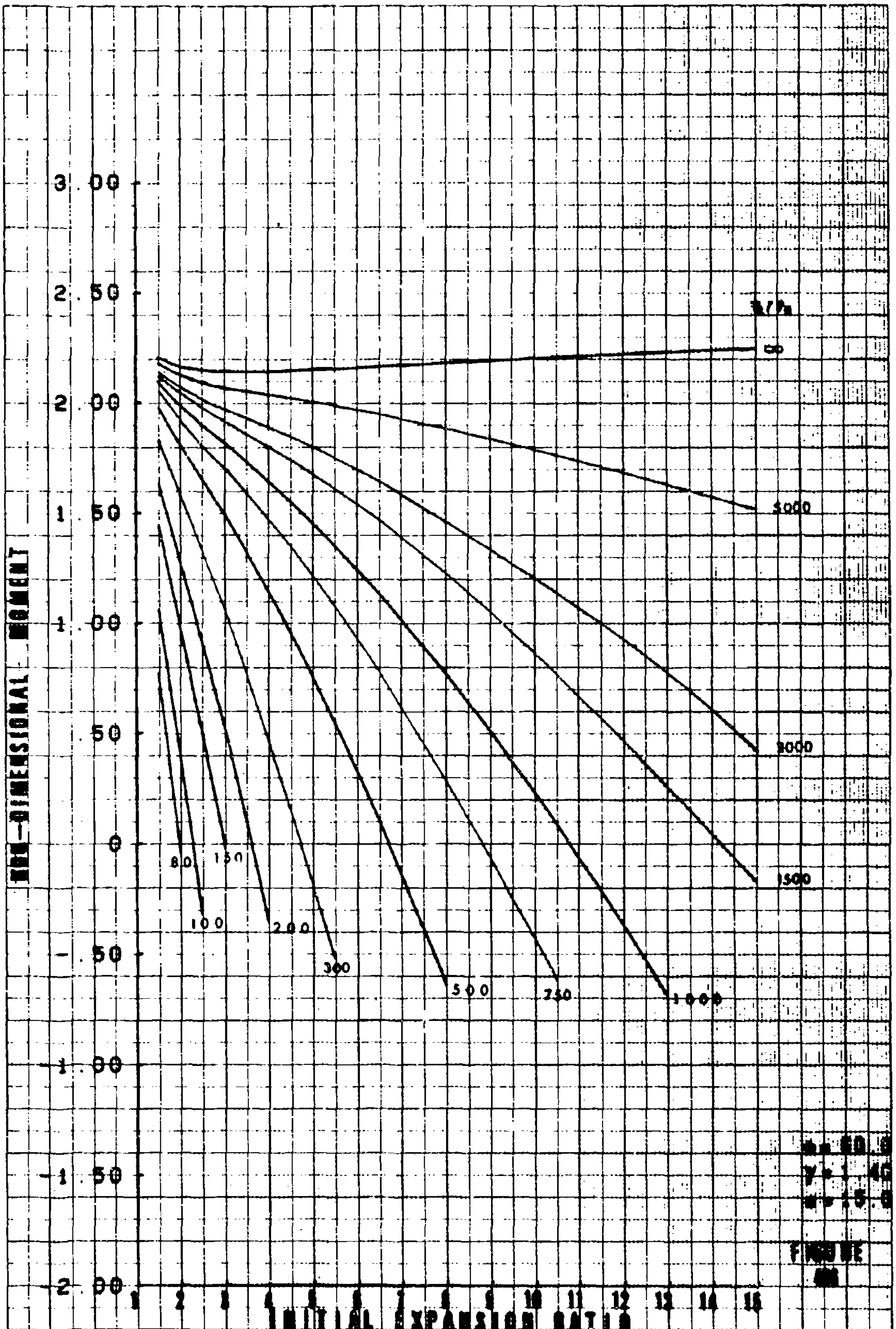

THRUST DEFLECTION ANGLE DEGREES
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
-1.0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
INITIAL EXPANSION RATIO
∞
1000
500
200
150
100
80
60
50
= 55.0
γ = 1.40
= 13.0
FIGURE

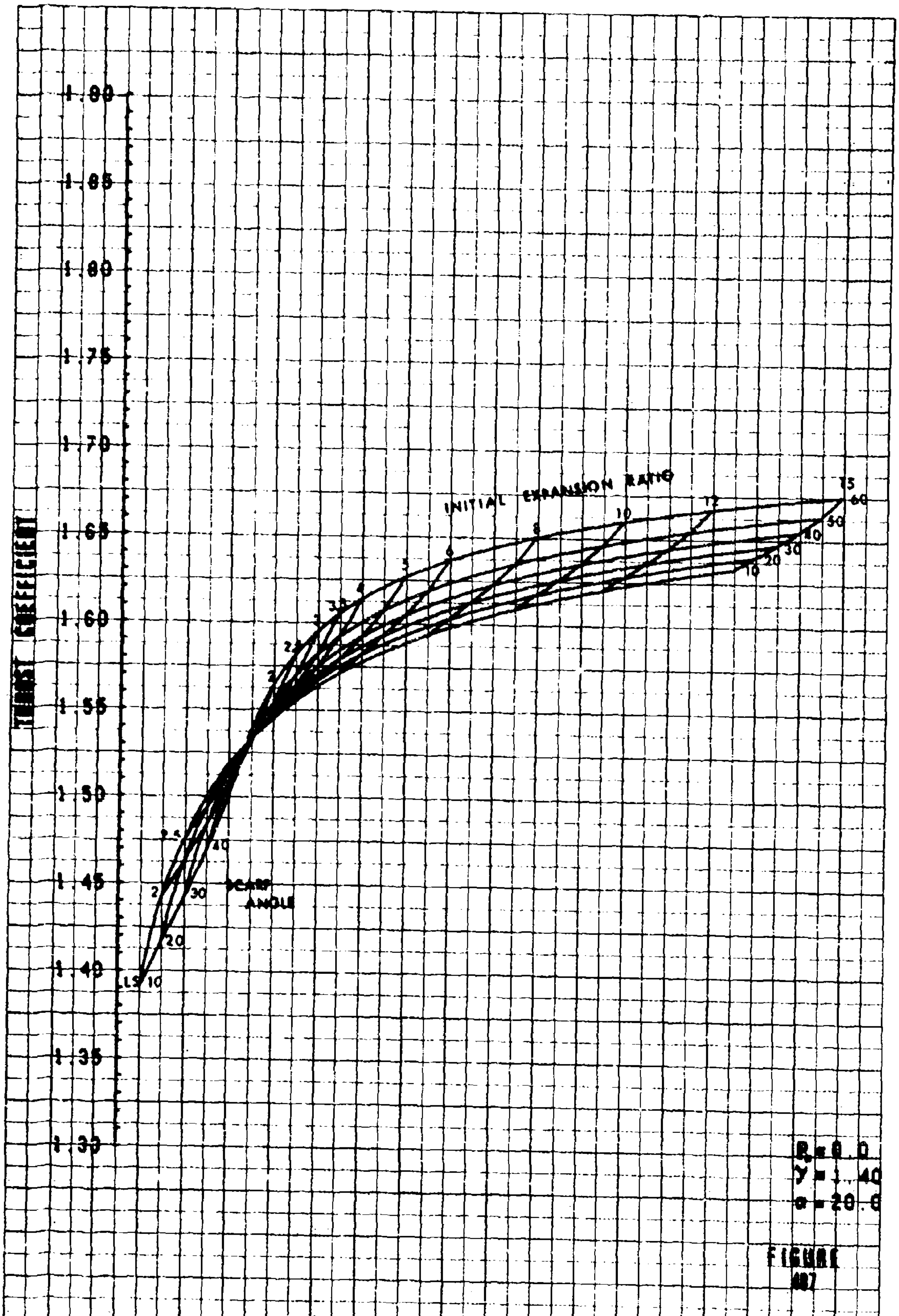

2.00
1.50
1.00
.50
0
-.50
-1.00
-1.50
-2.00
-2.50
-3.00
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
50
60
80
100
150
200
300
500
750
1000
2000

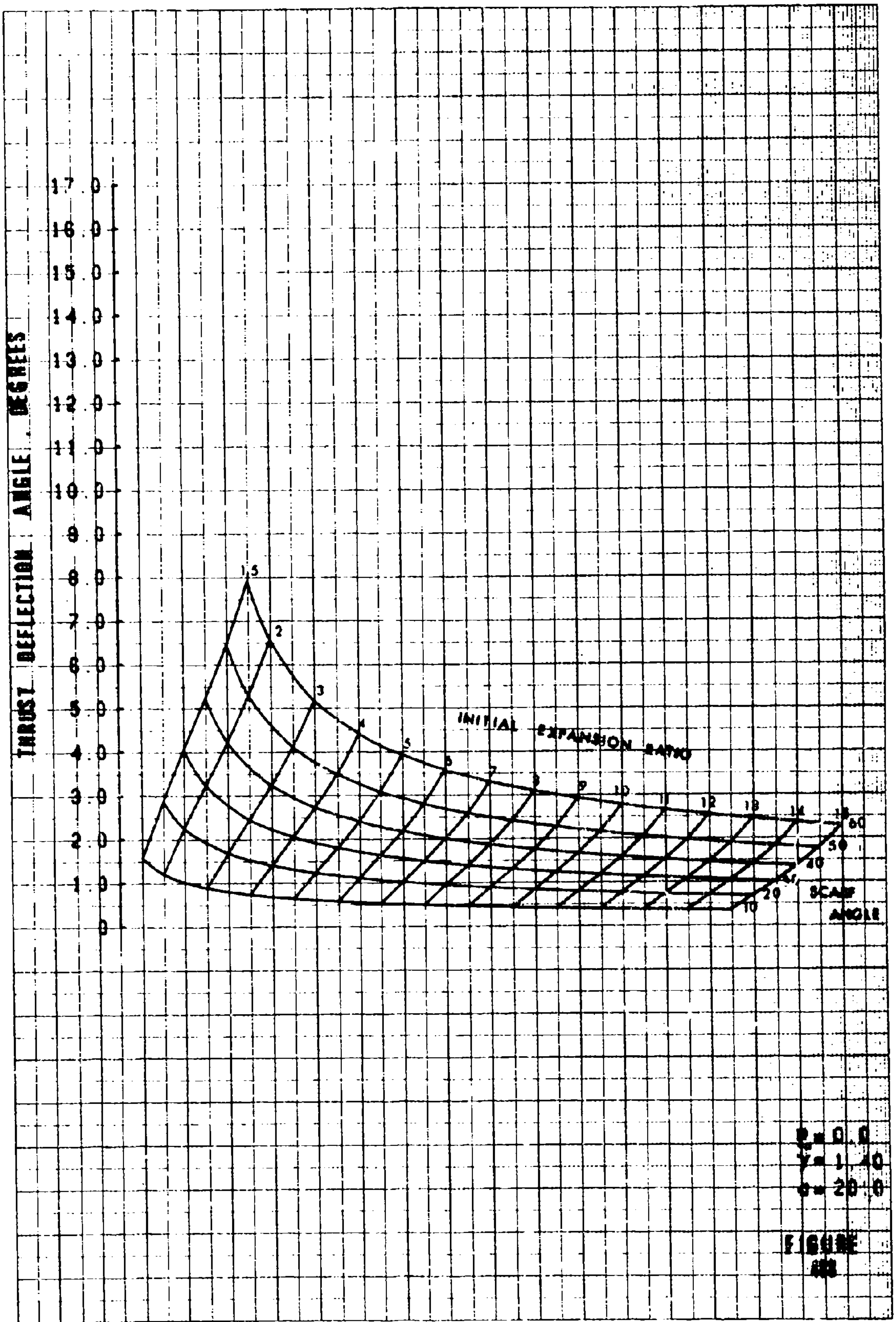

THRUST COEFFICIENT
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
INITIAL EXPANSION RATIO
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
P_c/P_e
∞
1000
500
200
150
100
80
ϕ = 60.0
γ = 1.40
θ = 15.0
FIGURE

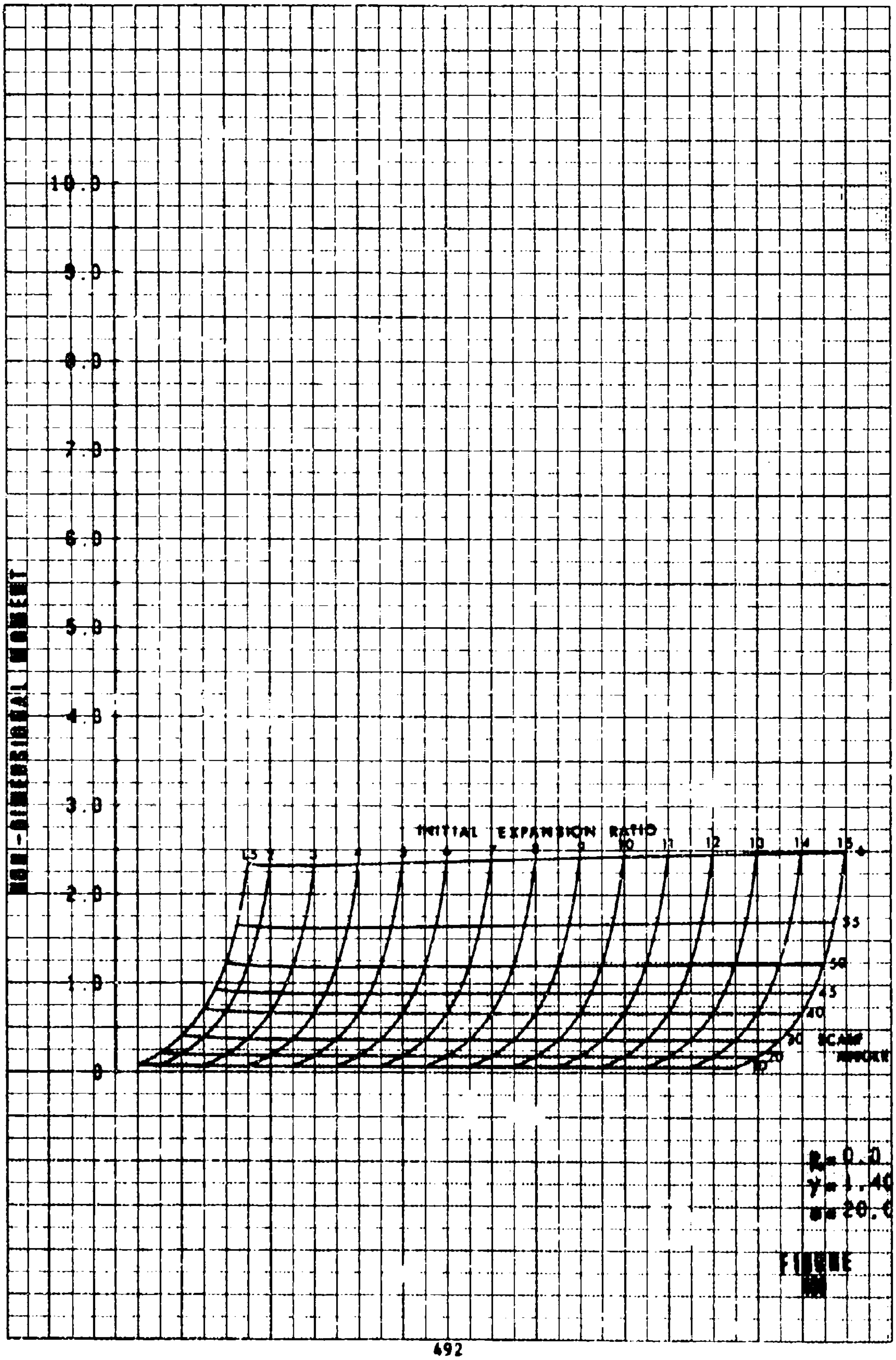


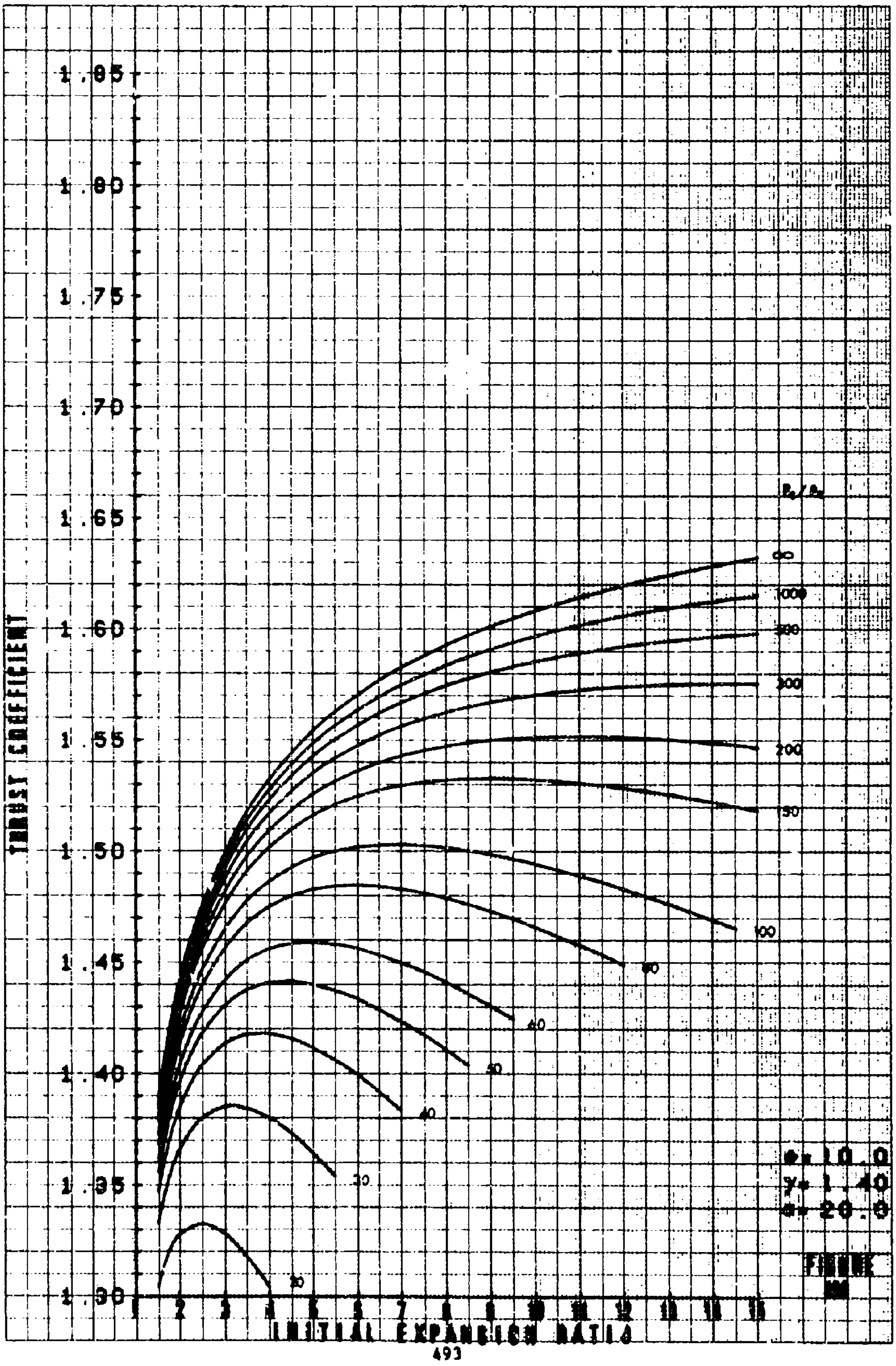
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
60
100
150
200
500
1000
∞
FIGURE

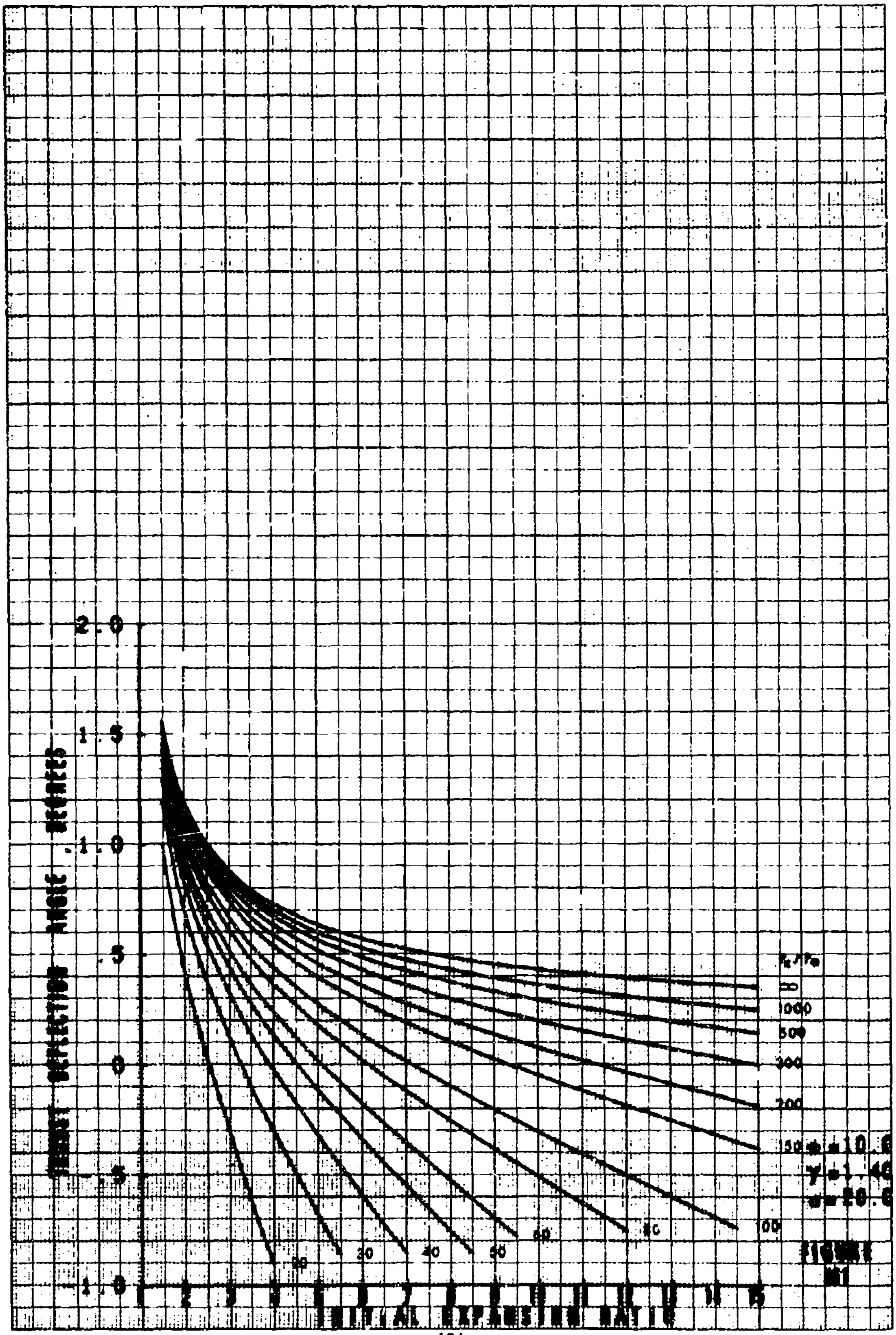

3.00
2.50
2.00
1.50
1.00
.50
0
-.50
-1.00
-1.50
-2.00
∞
5000
3000
1500
1000
750
500
300
200
150
100
80
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
INITIAL EXPANSION RATIO

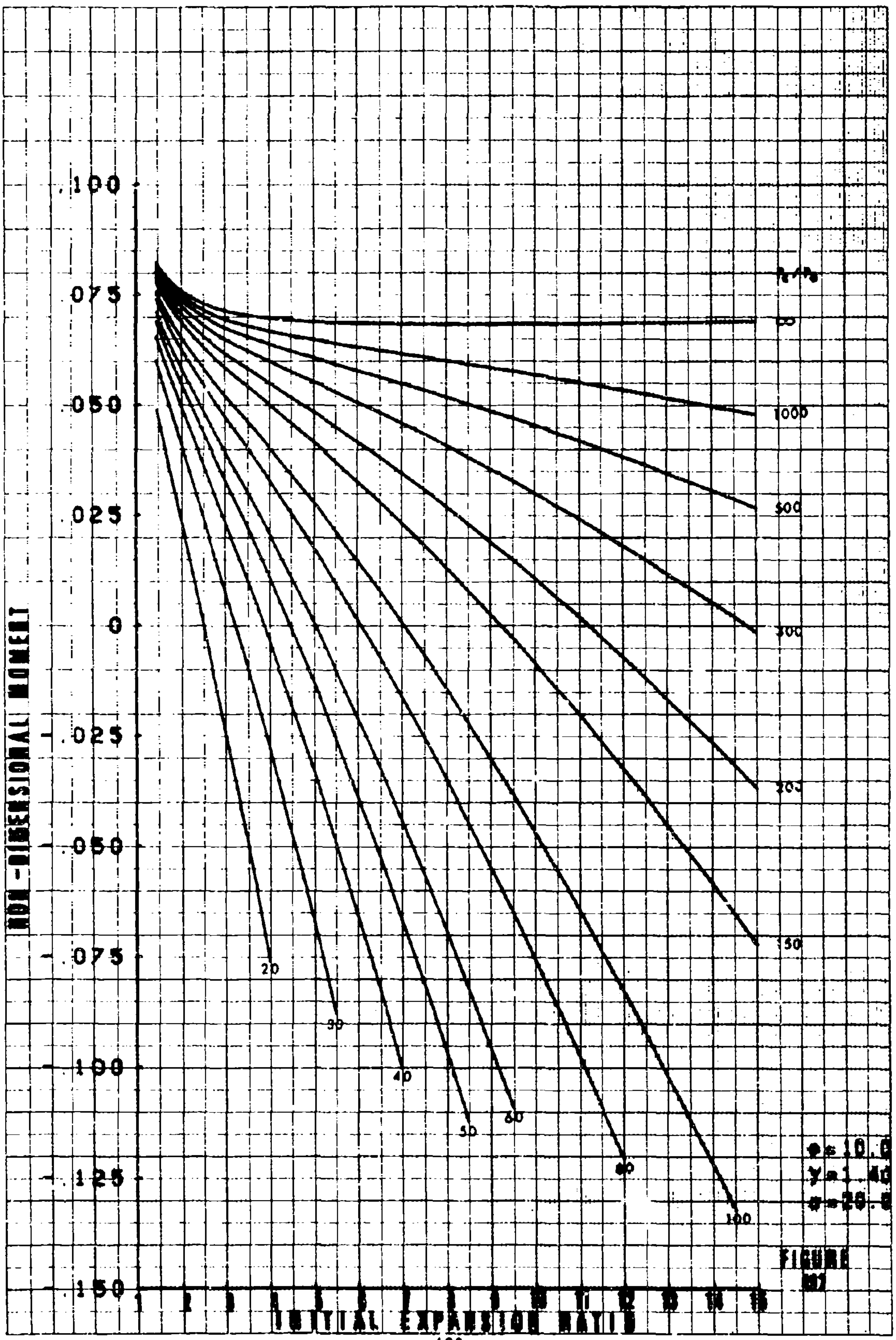

THRUST COEFFICIENT
1.90
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
INITIAL EXPANSION RATIO
SCARF ANGLE
R_e = 0.0
γ = 1.40
α = 20.0
FIGURE
487

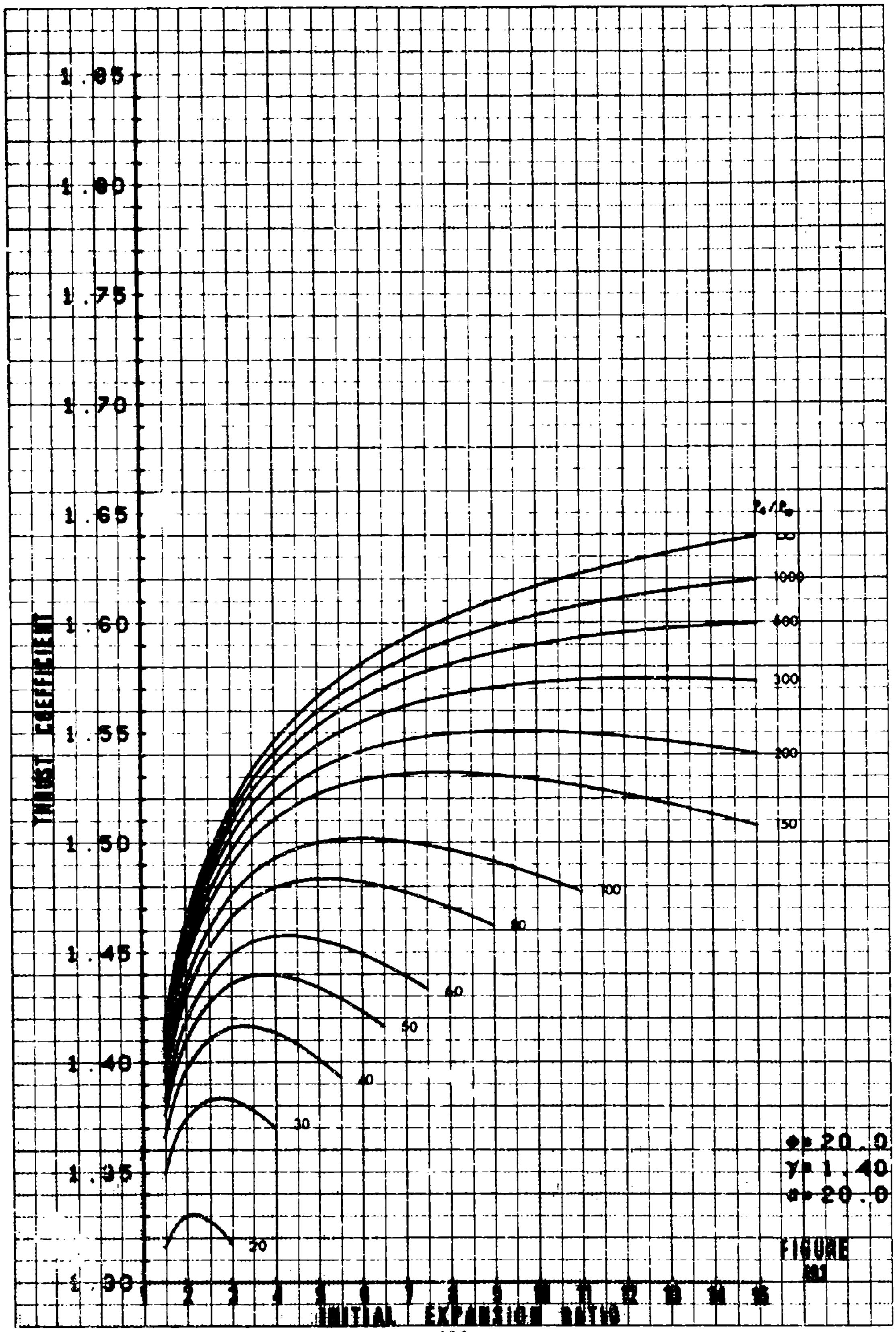

THRUST DEFLECTION ANGLE, DEGREES
17.0
16.0
15.0
14.0
13.0
12.0
11.0
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
INITIAL EXPANSION RATIO
1.5
2
3
4
5
6
7
8
9
10
11
12
13
14
15
60
50
40
20
10
SCARF ANGLE
= 0.0
= 1.40
= 20.0
FIGURE

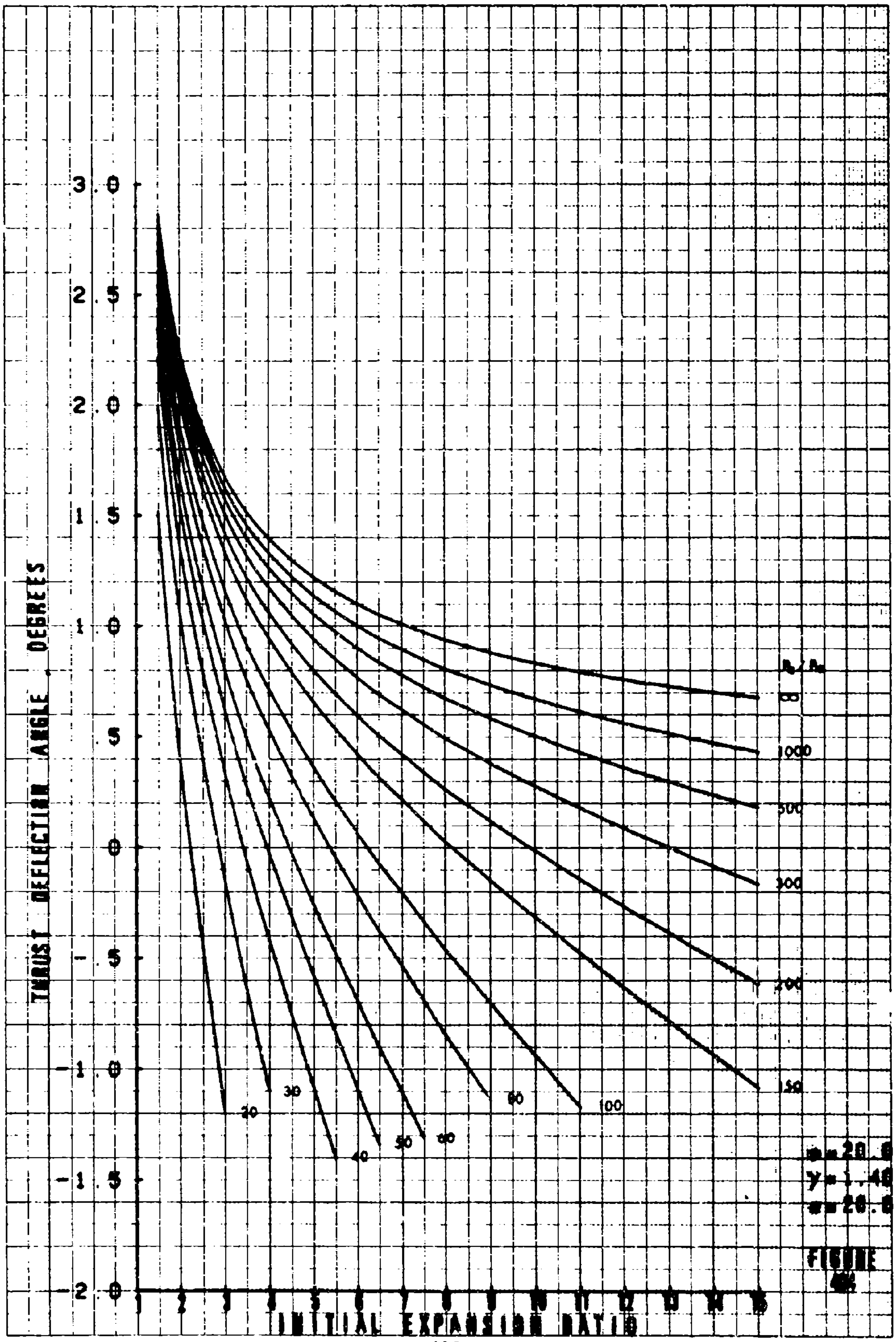

INITIAL EXPANSION RATIO
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0

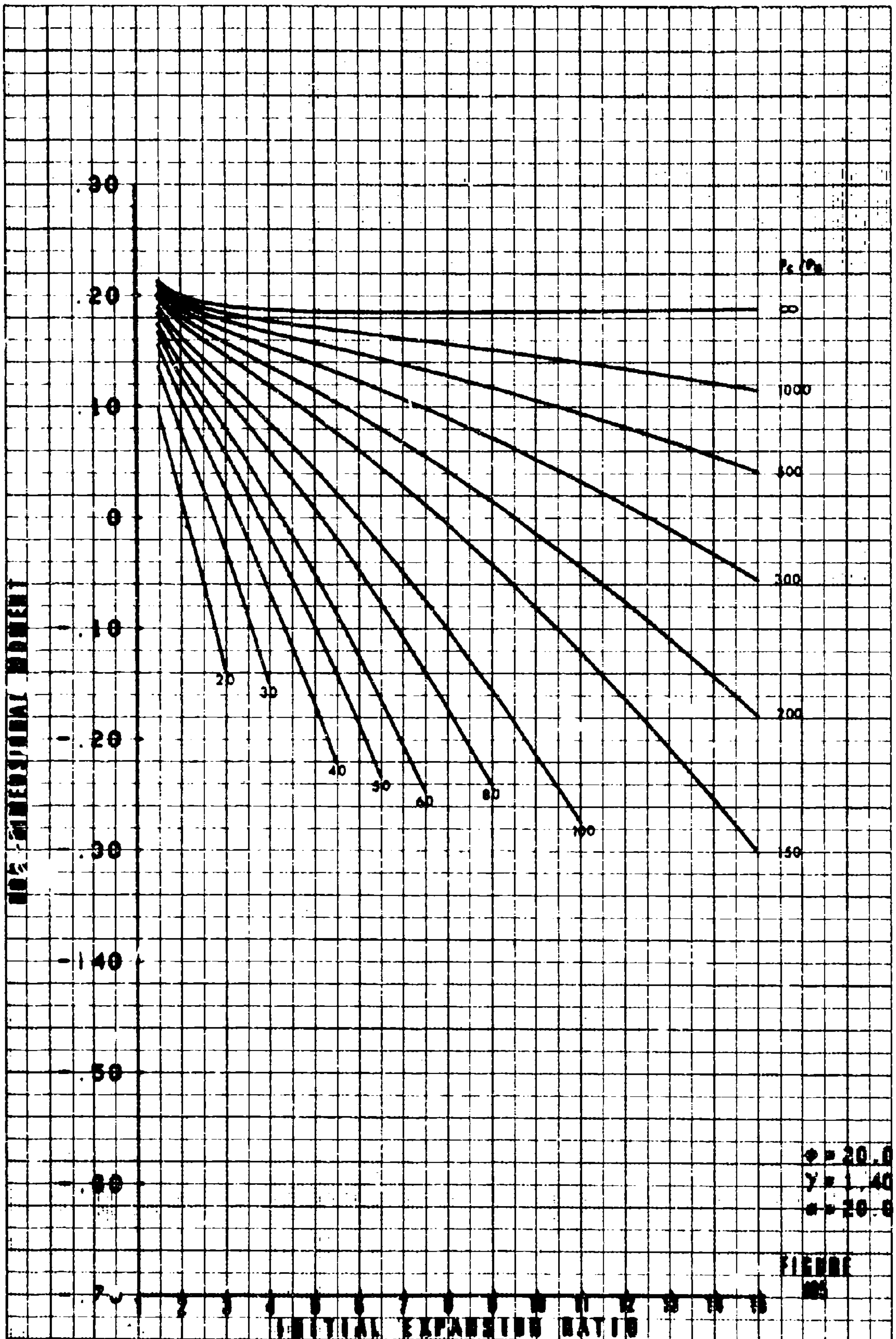

THRUST COEFFICIENT
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
INITIAL EXPANSION RATIO
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
∞
1000
500
300
200
150
100
80
60
50
40
30
20
γ= 1.40
FIGURE


2.0
1.5
1.0
.5
0
∞
1000
500
300
200
150
100
30
20
40
50

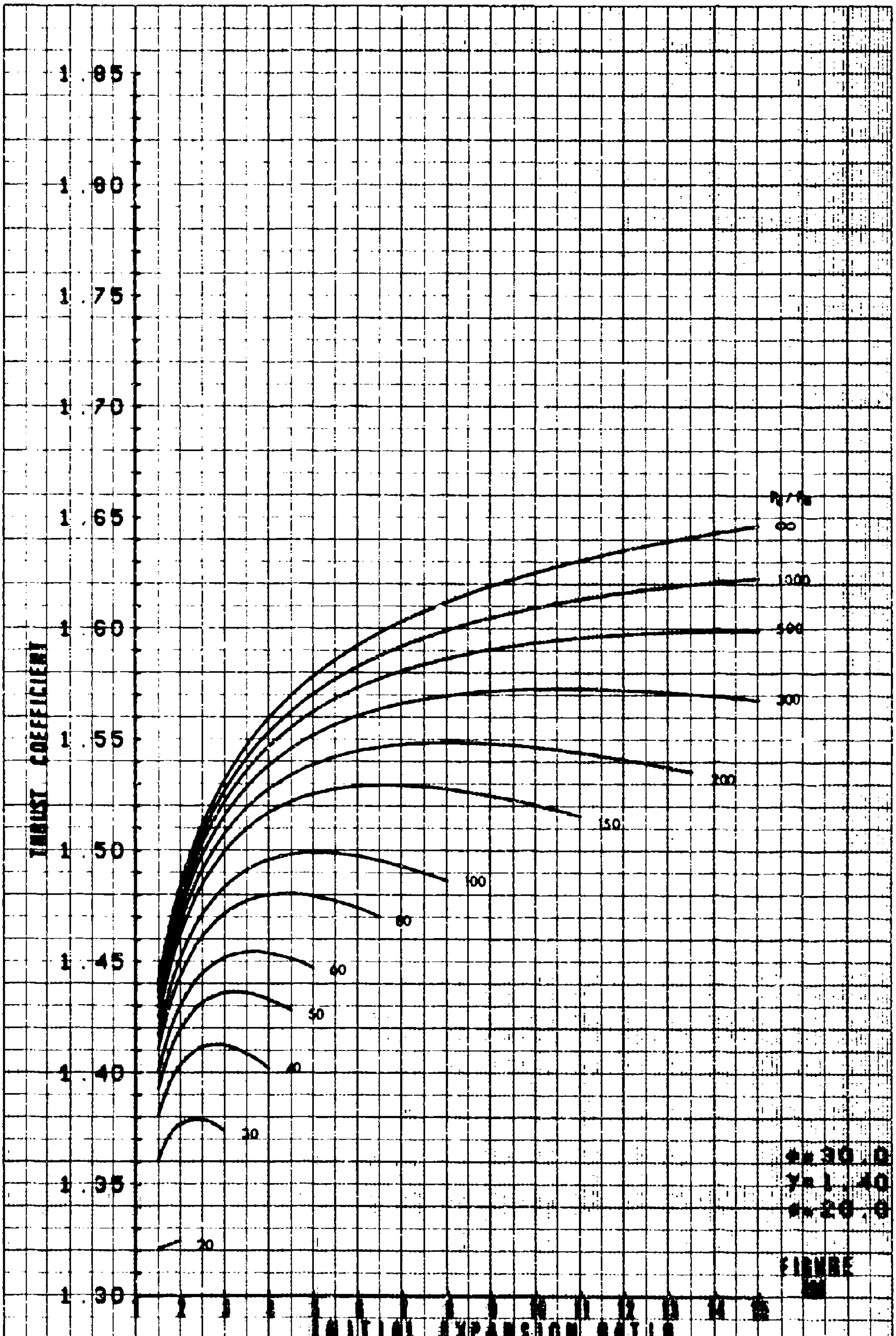

.100
.075
.050
.025
0
-.025
-.050
-.075
-.100
-.125
-.150
NON-DIMENSIONAL MOMENT
INITIAL EXPANSION RATIO
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
∞
1000
500
300
200
150
100
80
60
50
40
30
20
FIGURE

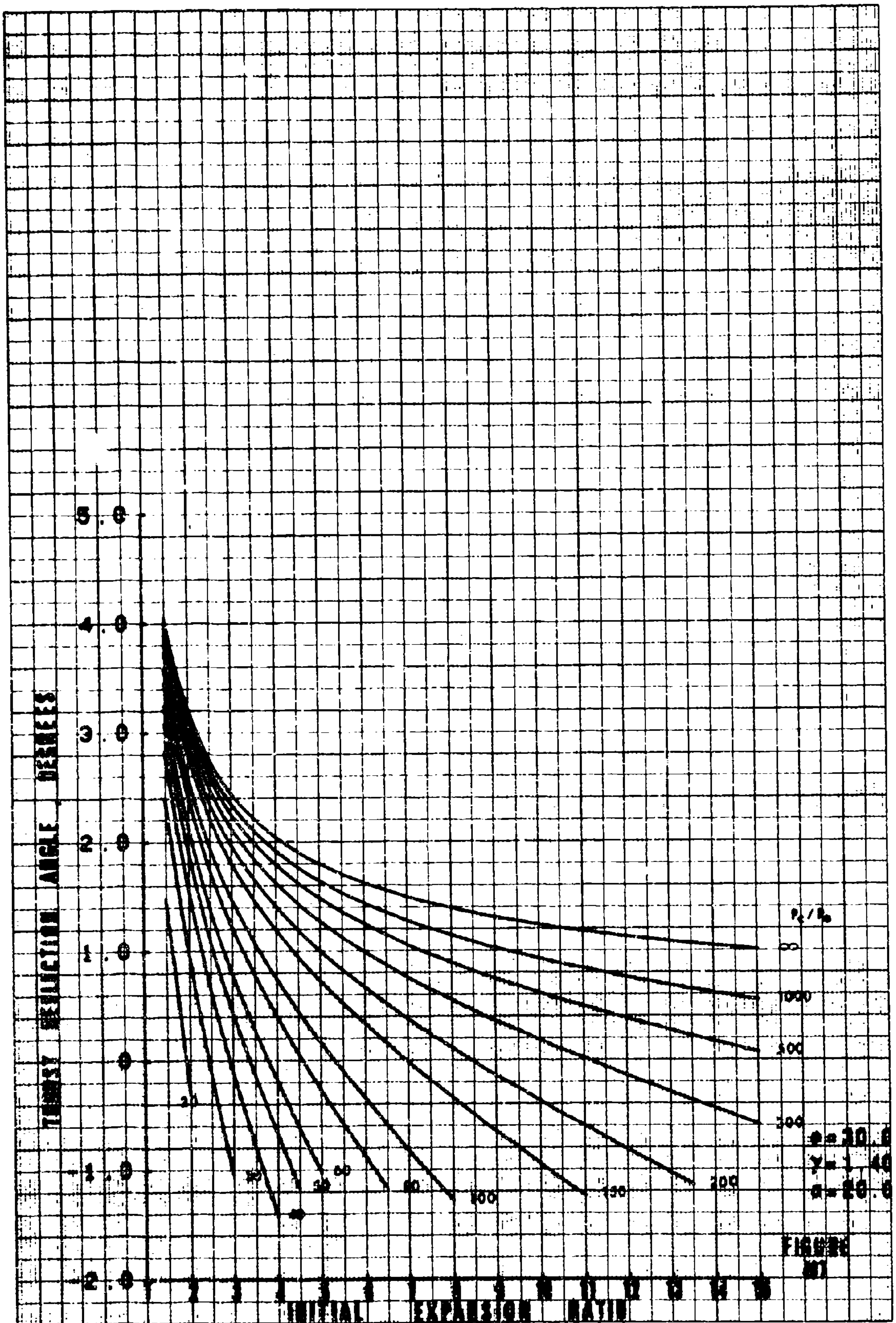

THRUST COEFFICIENT
INITIAL EXPANSION RATIO
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
∞
1000
300
200
150
100
60
50
40
30
20
γ = 1.40
FIGURE

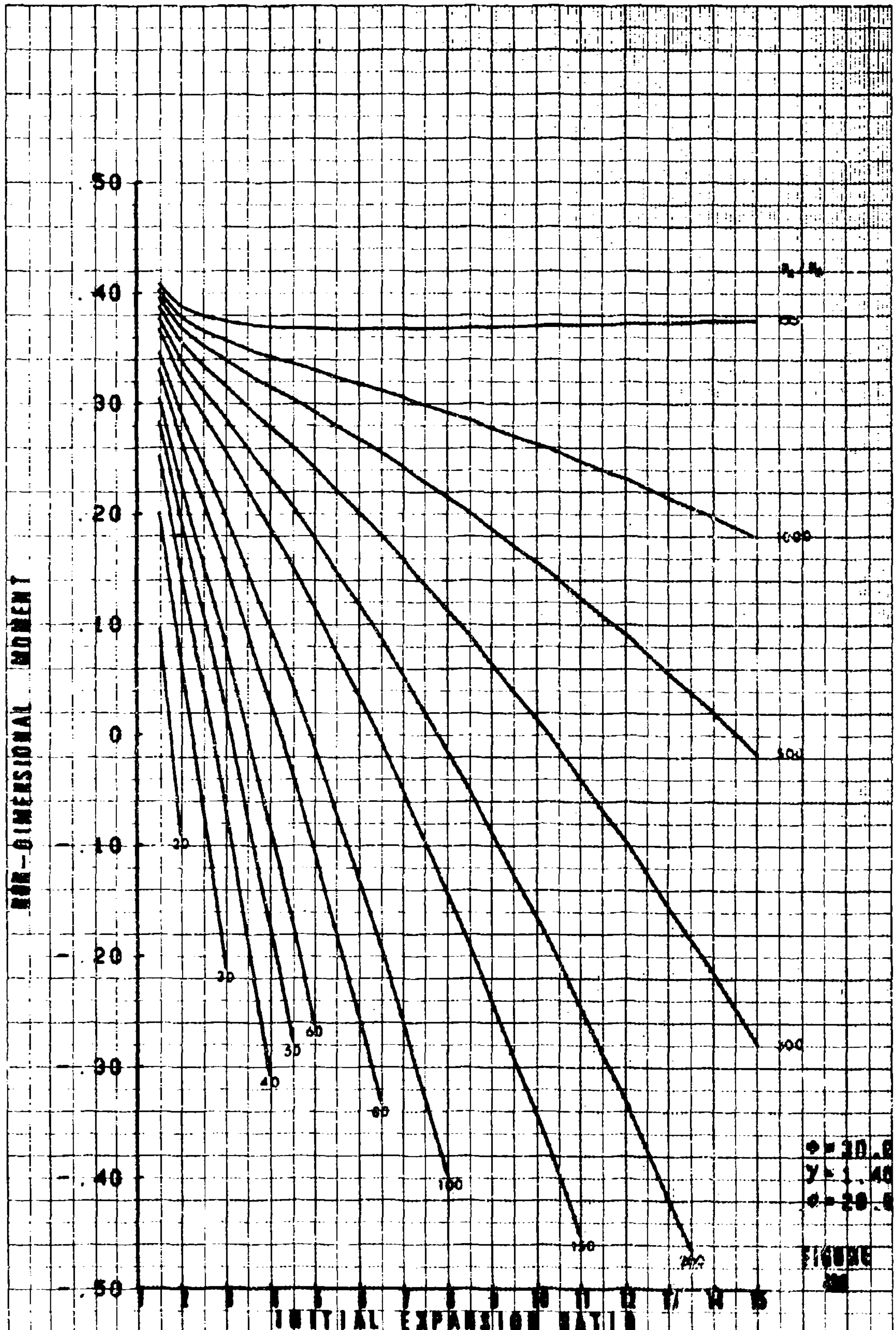

THRUST DEFLECTION ANGLE, DEGREES
3.0
2.5
2.0
1.5
1.0
.5
0
-.5
-1.0
-1.5
-2.0
INITIAL EXPANSION RATIO
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
∞
1000
500
300
200
150
20
30
40
50
60
80
100
FIGURE

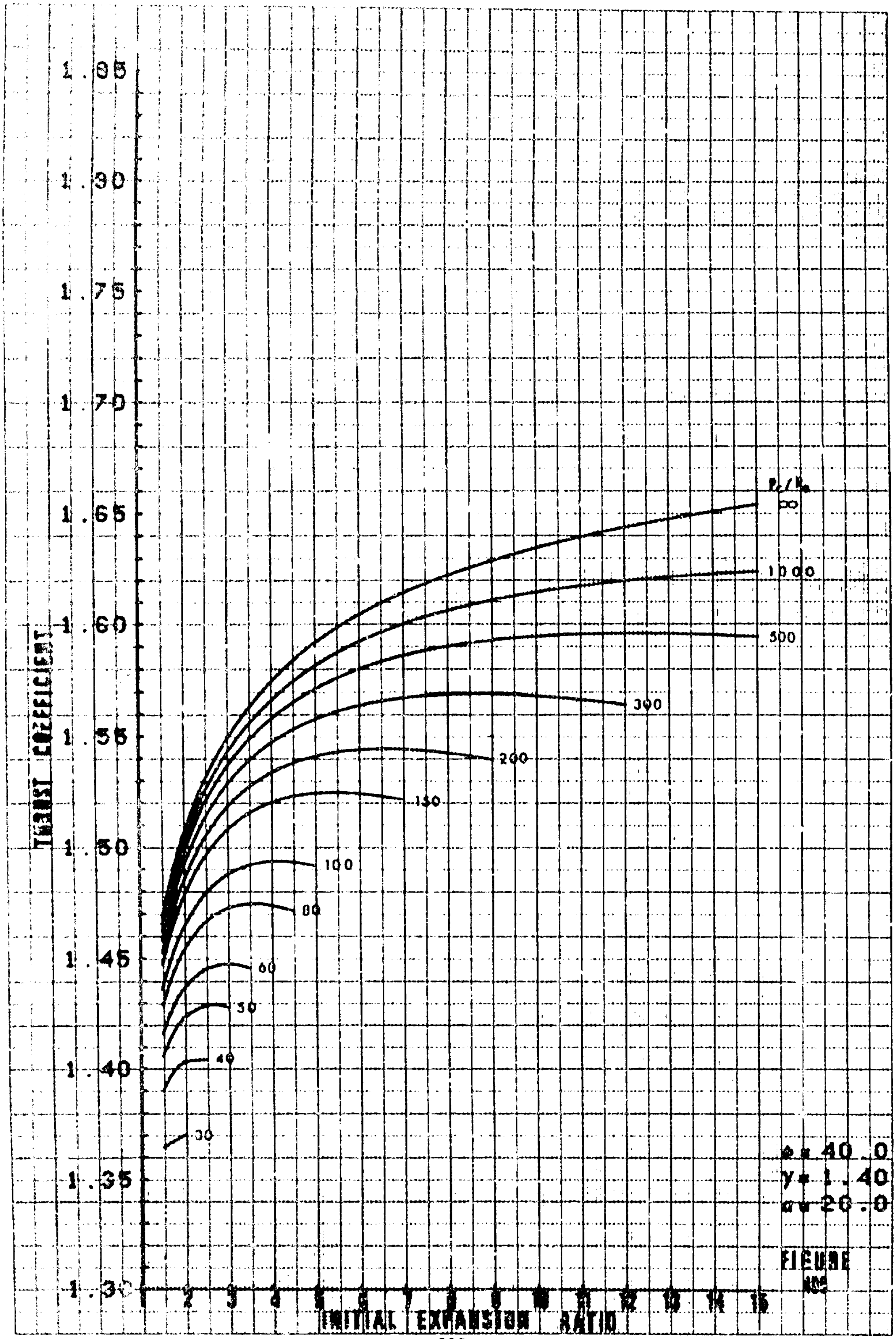


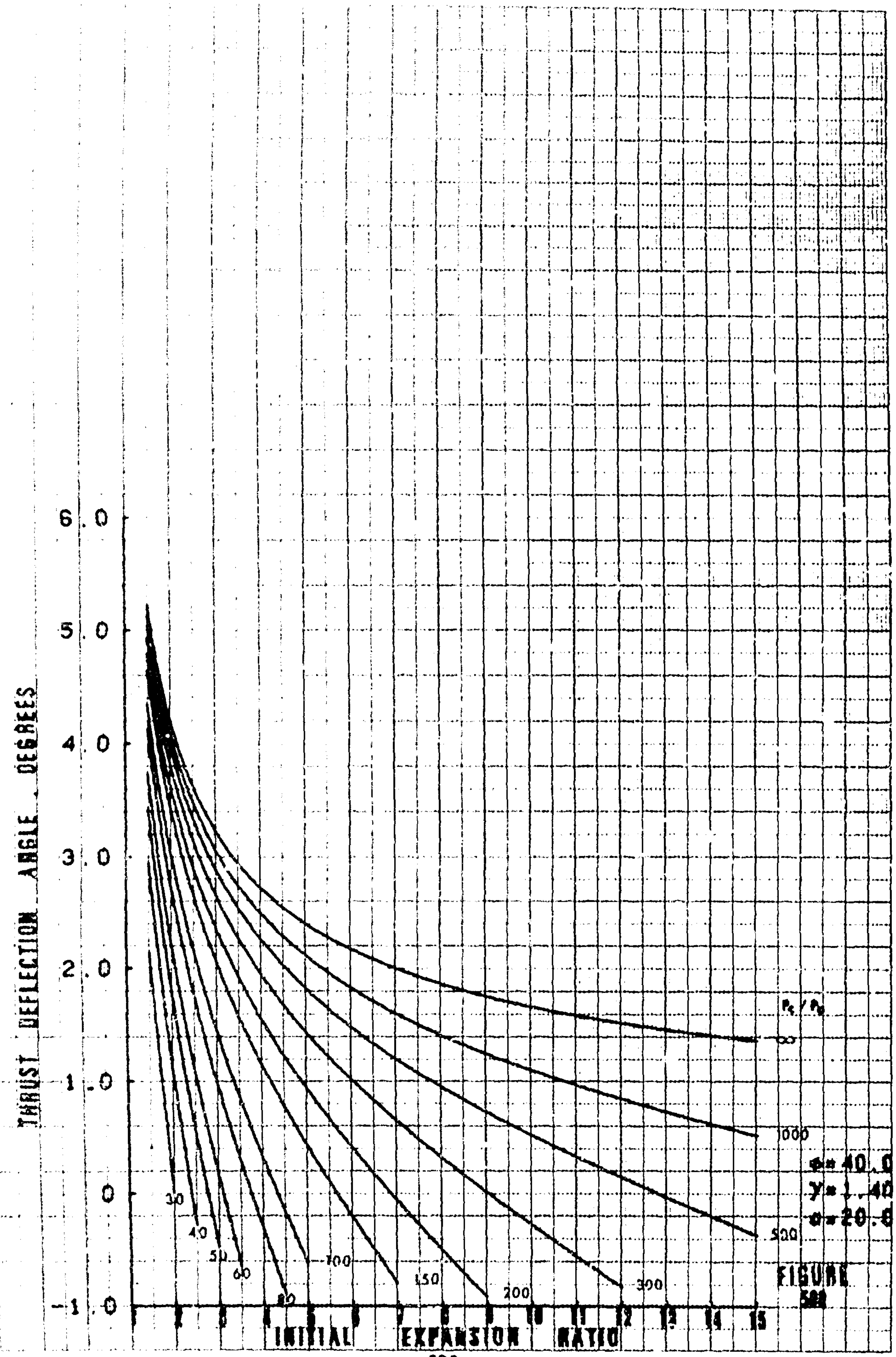
NON-DIMENSIONAL MOMENT
INITIAL EXPANSION RATIO
P_c/P_a
∞
1000
500
300
200
150
20
30
40
50
60
80
100
.30
.20
.10
0
-.10
-.20
-.30
-.40
-.50
-.60
-.70
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
ϕ = 20.0
γ = 1.40
α = 20.0
FIGURE


THRUST COEFFICIENT
INITIAL EXPANSION RATIO
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
∞
1000
500
300
200
150
100
80
60
50
40
30
20
FIGURE

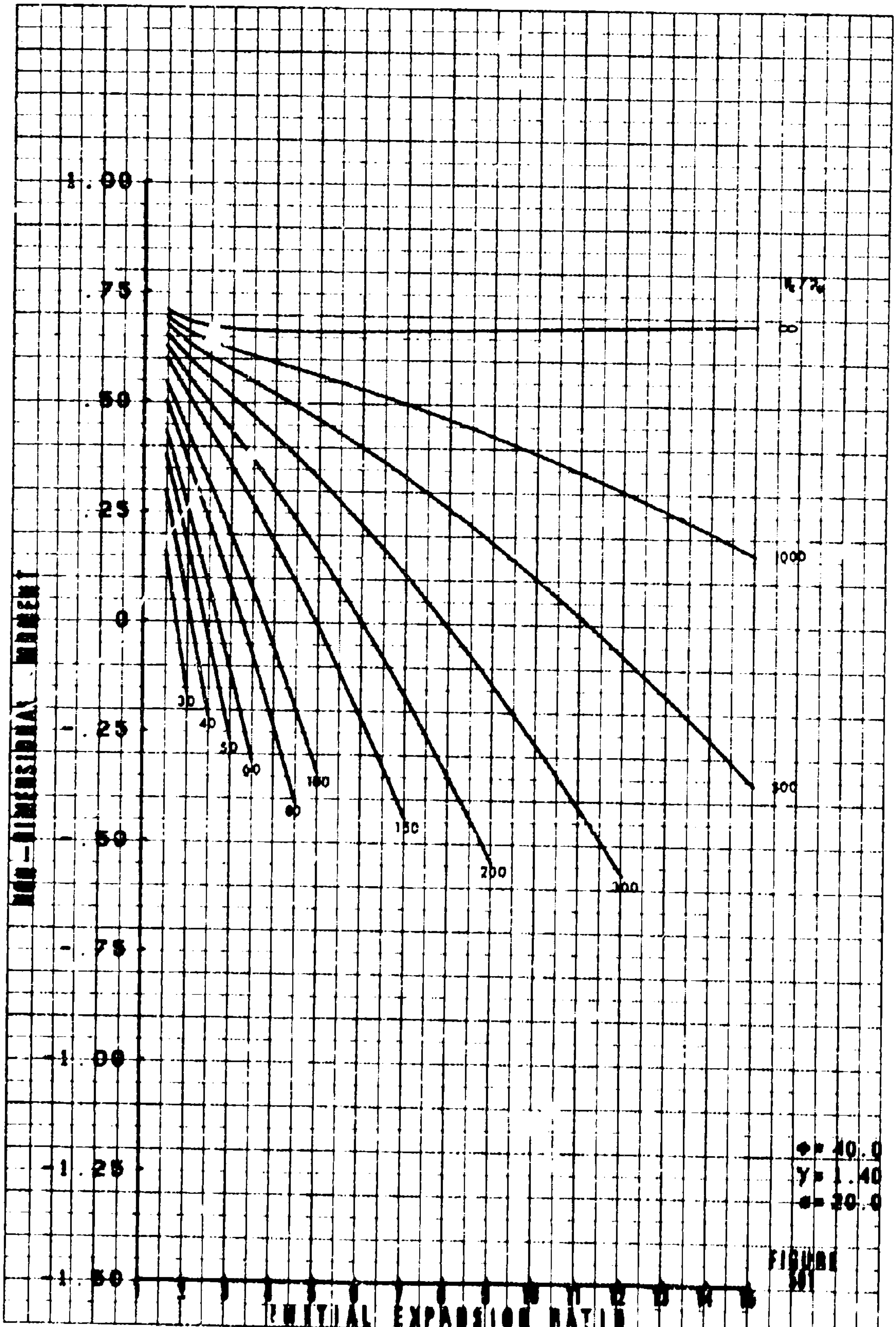

THRUST DEFLECTION ANGLE, DEGREES
5.0
4.0
3.0
2.0
1.0
0
-1.0
-2.0
Pc / Pa
∞
1000
500
300
200
150
100
80
60
50
40
30
20
FIGURE
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
INITIAL EXPANSION RATIO


NON-DIMENSIONAL MOMENT
INITIAL EXPANSION RATIO
.50
.40
.30
.20
.10
0
-.10
-.20
-.30
-.40
-.50
1000
500
300
150
100
80
60
50
40
30
20


THRUST COEFFICIENT
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
P_c/P_a
∞
1000
500
300
200
150
100
80
60
50
40
30
α = 40.0
γ = 1.40
α = 20.0
FIGURE

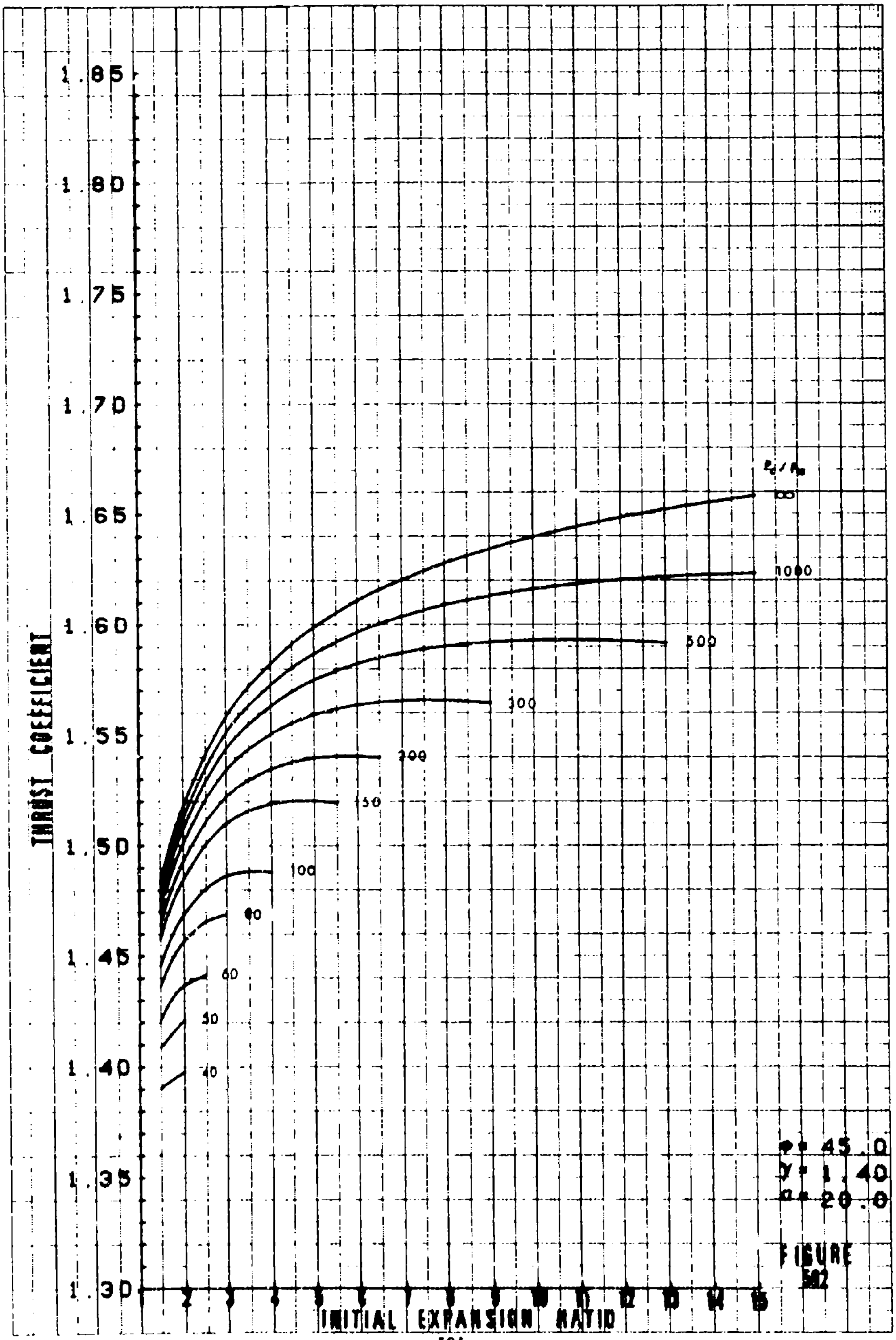


THRUST DEFLECTION ANGLE, DEGREES
6.0
5.0
4.0
3.0
2.0
1.0
0
-1.0
INITIAL EXPANSION RATIO
2
3
4
5
6
7
8
9
10
11
12
13
14
15
P_c/P_a
∞
1000
500
300
200
150
100
80
60
50
40
30
ϕ = 40.0
γ = 1.40
α = 20.0
FIGURE



1.00
.75
.50
.25
0
-.25
-.50
-.75
-1.00
-1.25
-1.50
NON-DIMENSIONAL MOMENT
INITIAL EXPANSION RATIO
30
40
50
60
80
100
150
200
300
500
1000
∞
φ = 40.0
γ = 1.40
α = 20.0

FIGURE 501



1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
THRUST COEFFICIENT
INITIAL EXPANSION RATIO
2
3
4
5
6
7
8
9
10
11
12
13
14
15
1000
500
300
200
150
100
80
60
50
40
φ = 45.0
γ = 1.40
α = 20.0

FIGURE 502

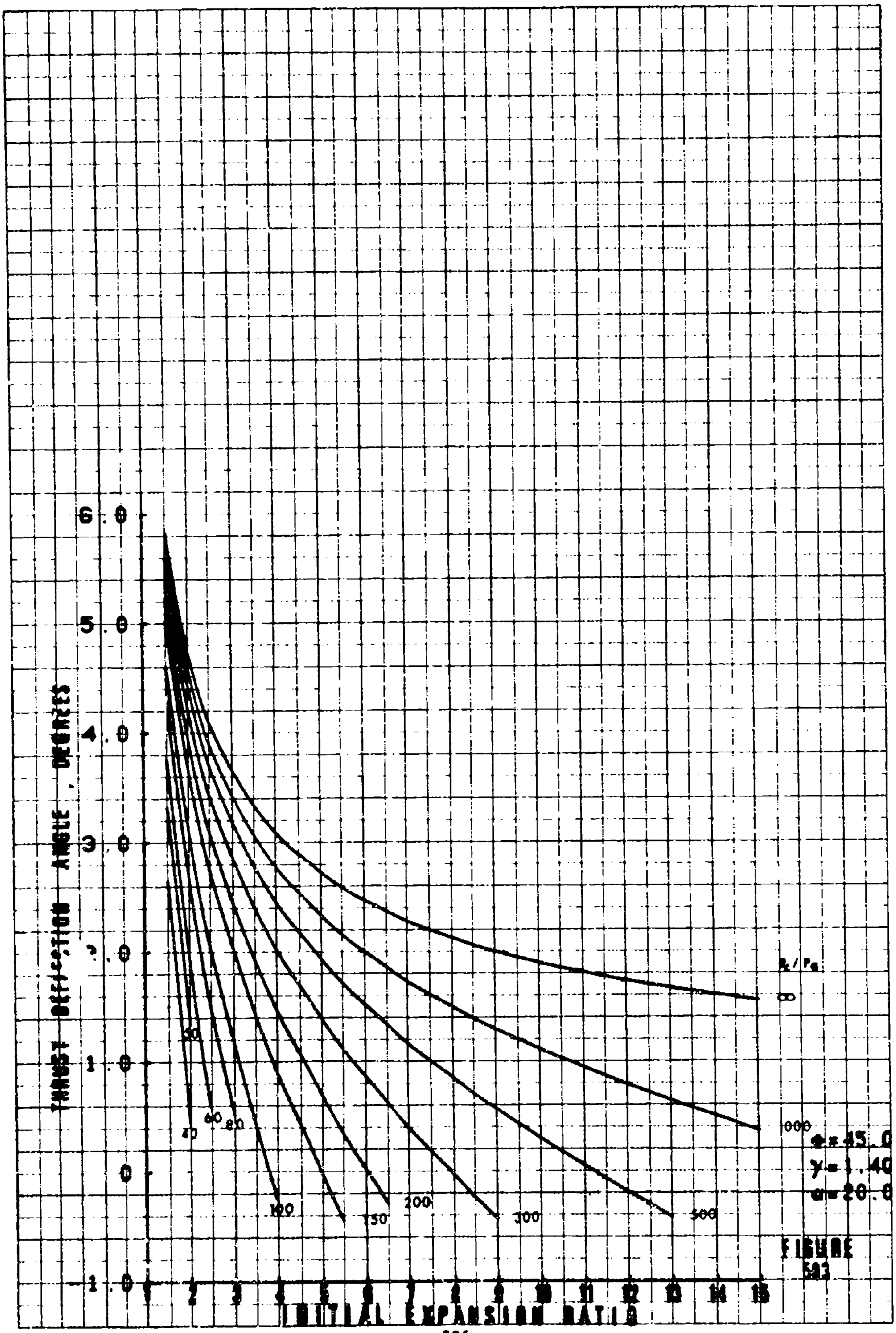
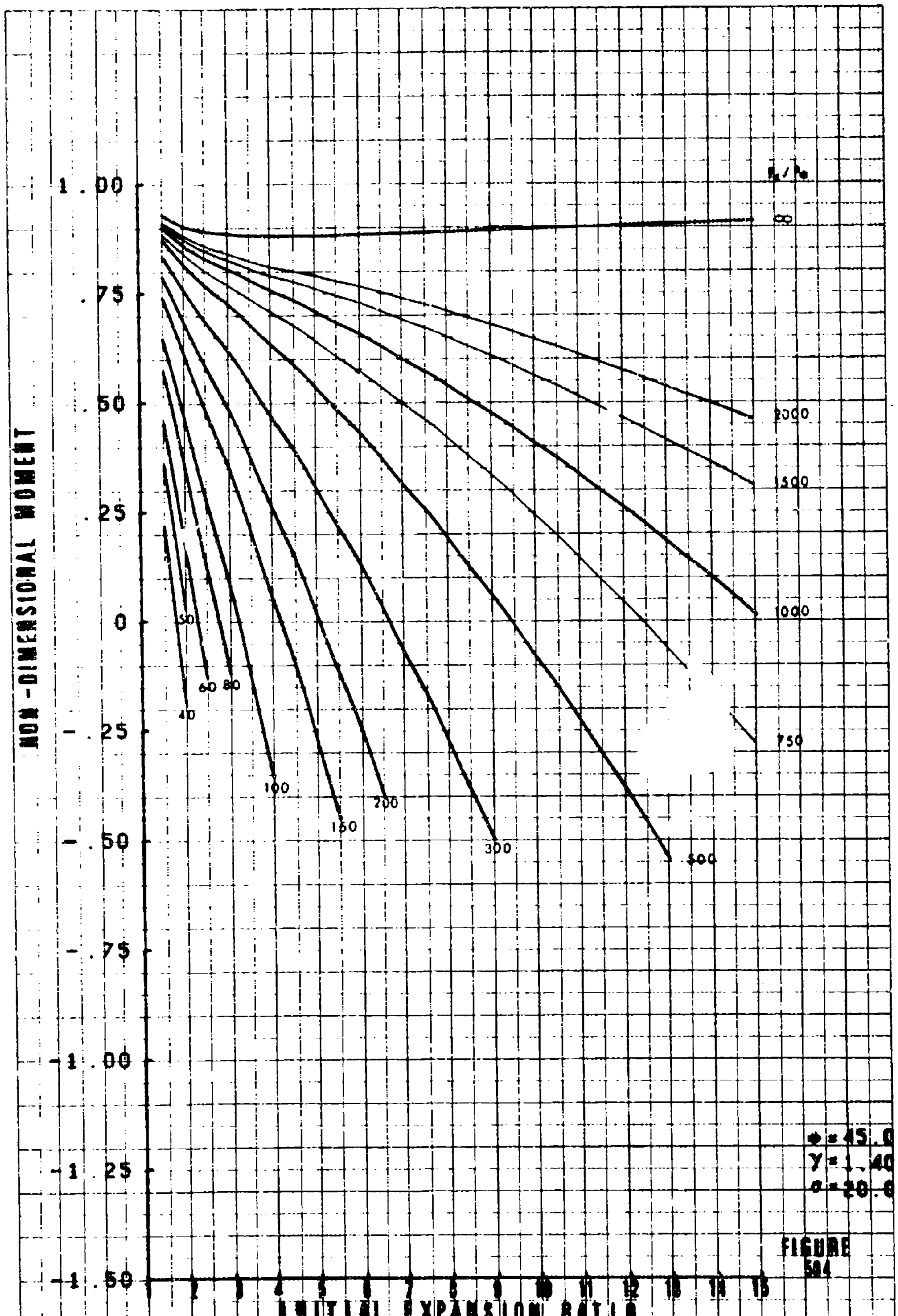
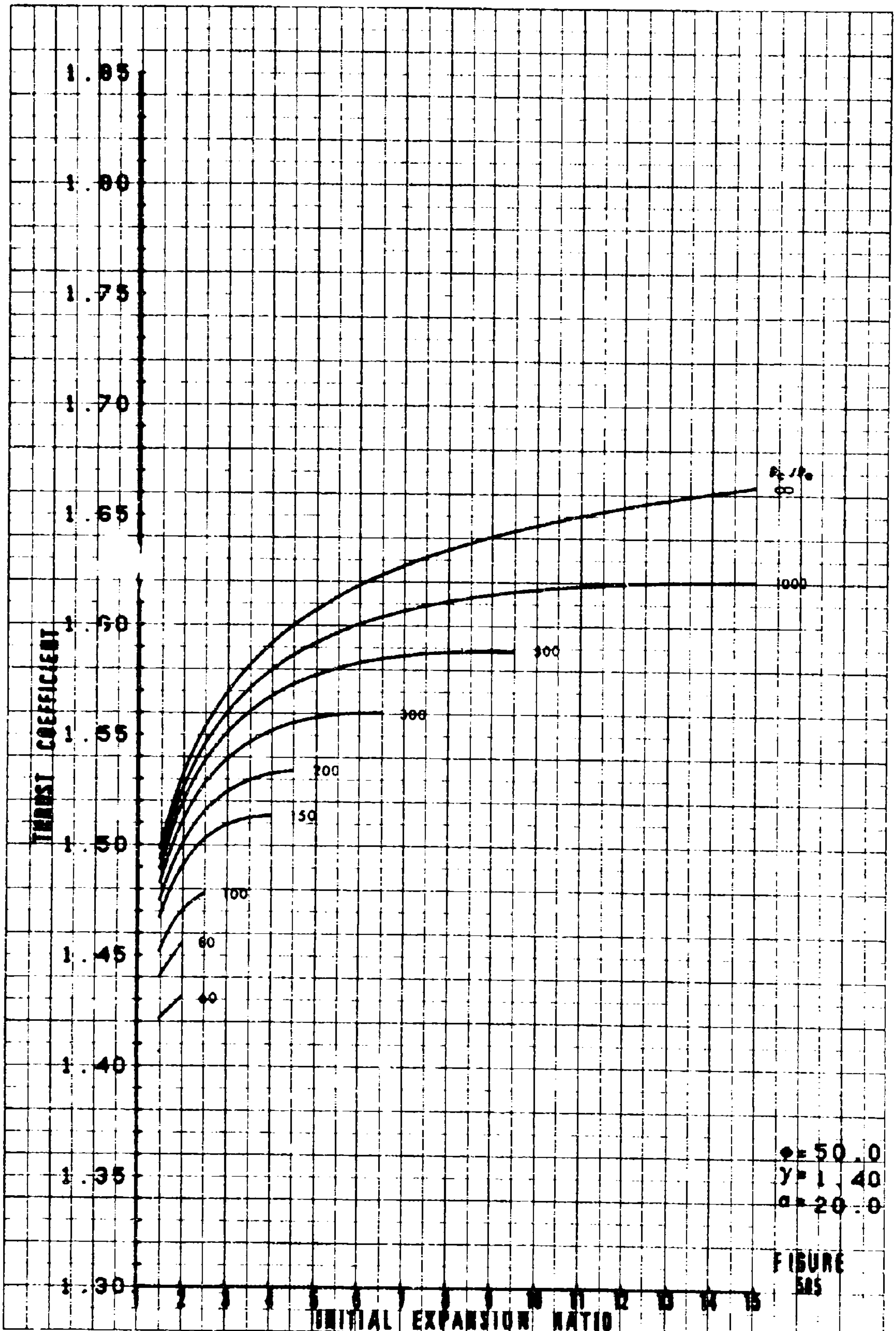

6.0
5.0
4.0
3.0
2.0
1.0
0
-1.0
THRUST DEFLECTION ANGLE , DEGREES
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
INITIAL EXPANSION RATIO
40
50
60
80
100
150
200
300
500
1000
∞
φ=45.0
γ=1.40
α=20.0

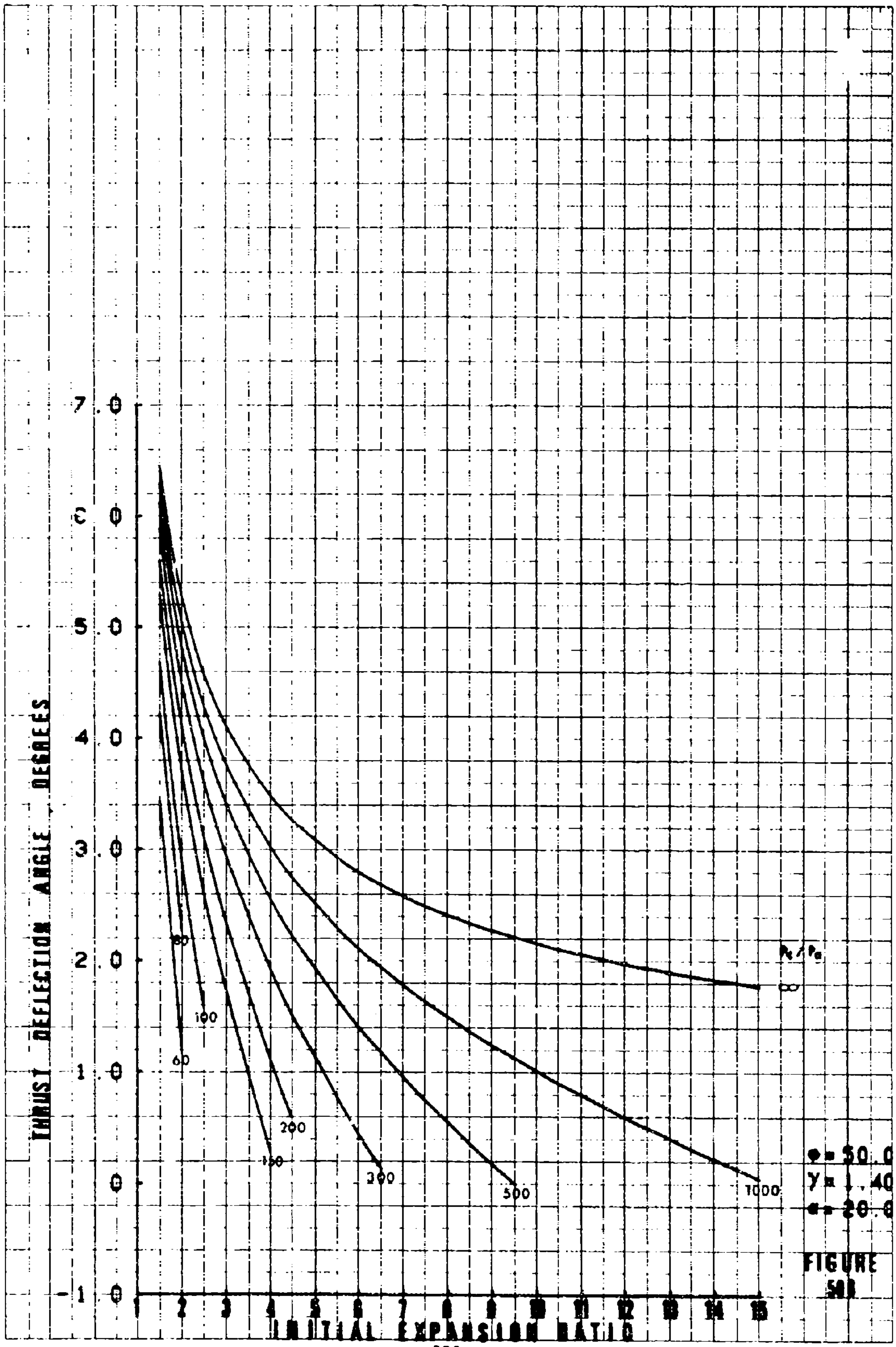
FIGURE 503

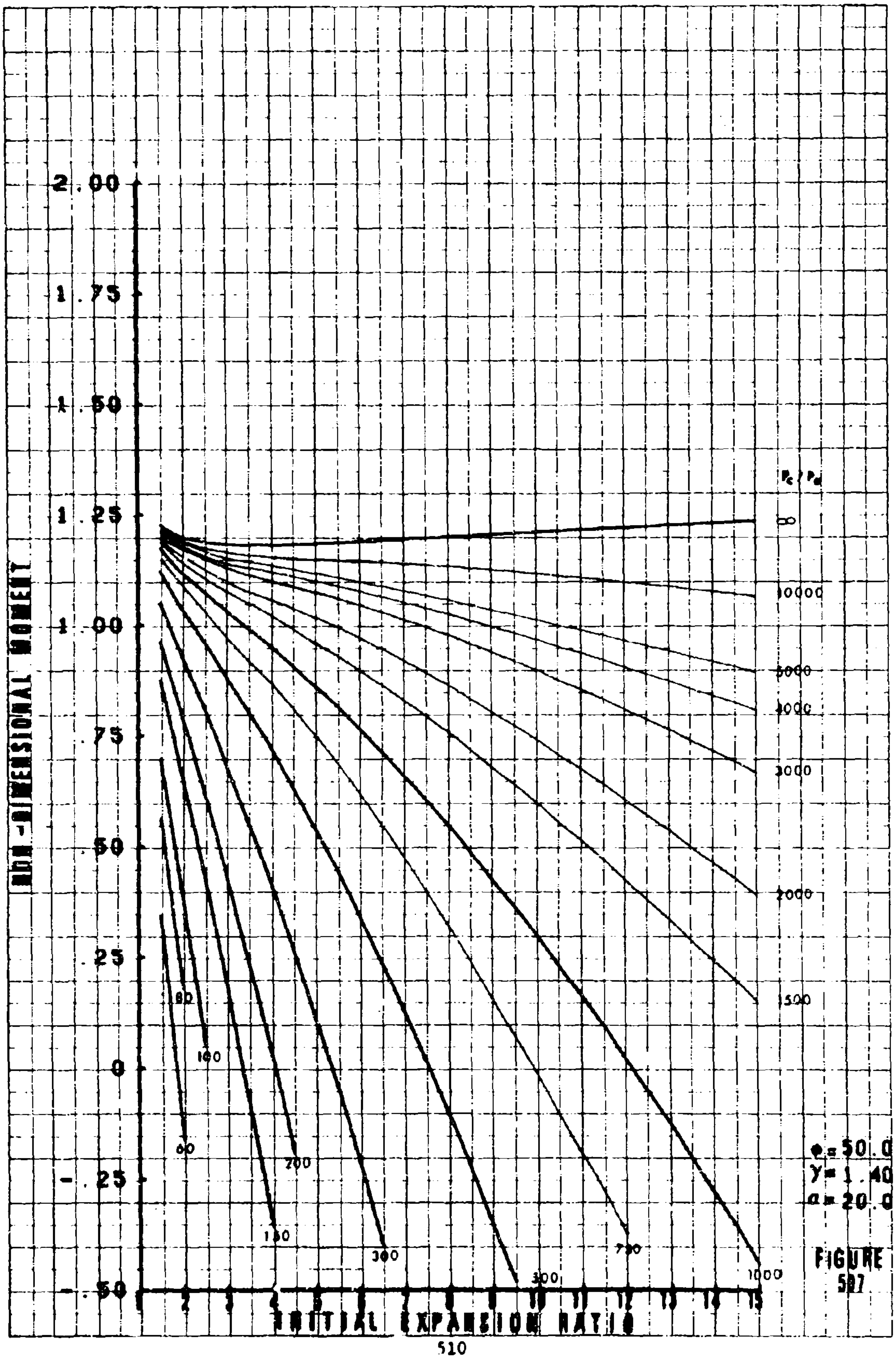


NON-DIMENSIONAL MOMENT
INITIAL EXPANSION RATIO
P_c/P_a
∞
2000
1500
1000
750
500
300
200
160
100
80
60
50
40
1.00
.75
.50
.25
0
-.25
-.50
-.75
-1.00
-1.25
-1.50
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
ϕ = 45.0
γ = 1.40
α = 20.0

FIGURE 504


THRUST COEFFICIENT
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
INITIAL EXPANSION RATIO
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
p_t/p_e
∞
1000
500
300
200
150
100
60
40
Φ = 50.0
γ = 1.40
α = 20.0
FIGURE 505


THRUST DEFLECTION ANGLE , DEGREES
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
-1.0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
P_c / P_a
∞
60
80
100
150
200
300
500
1000
φ = 50.0
γ = 1.40
α = 20.0
FIGURE



NON-DIMENSIONAL MOMENT
2.00
1.75
1.50
1.25
1.00
.75
.50
.25
0
-.25
-.50
INITIAL EXPANSION RATIO
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
P_c/P_a
∞
10000
5000
4000
3000
2000
1500
1000
700
500
300
200
150
100
80
60
ϕ = 50.0
γ = 1.40
α = 20.0

FIGURE 507

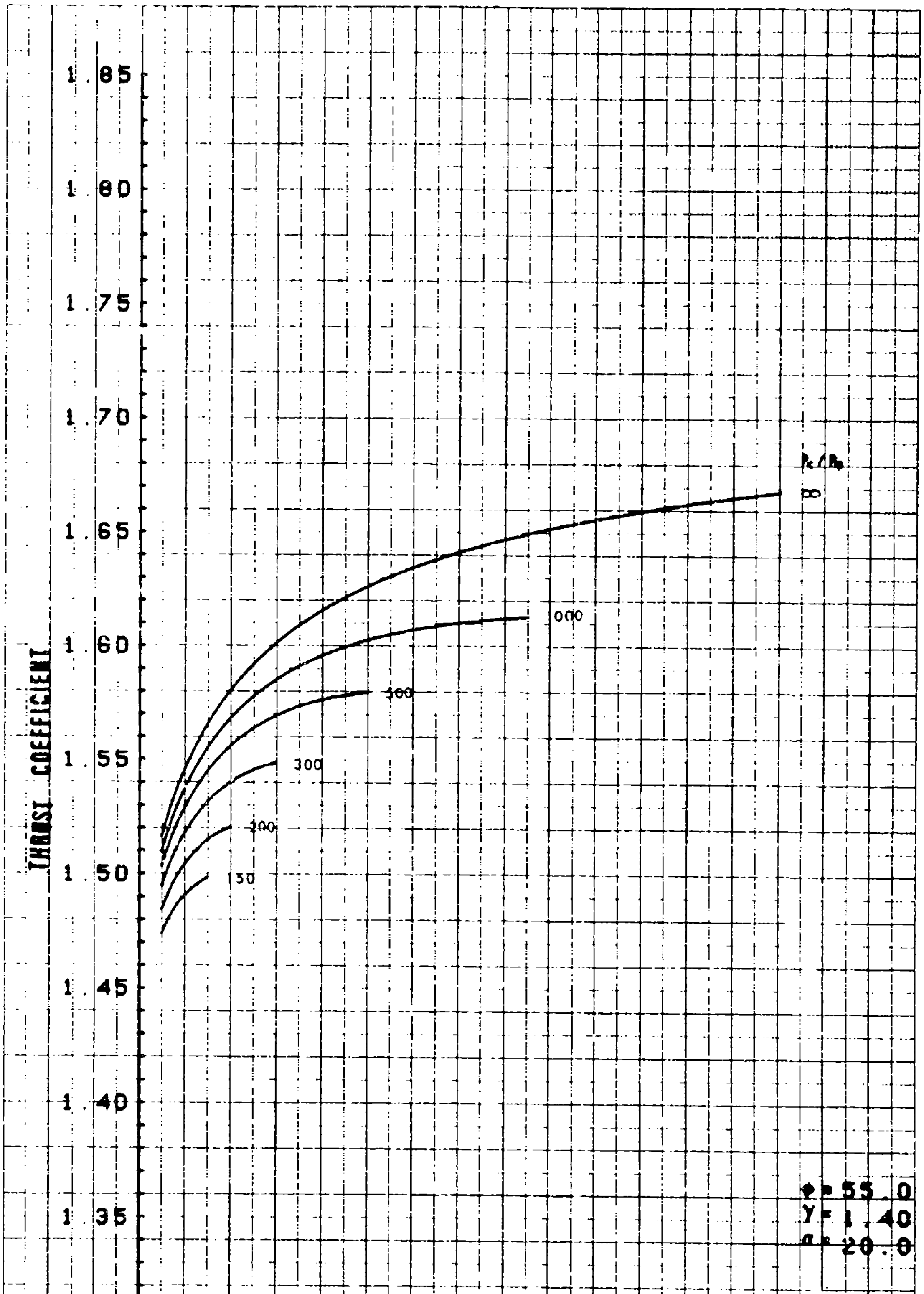
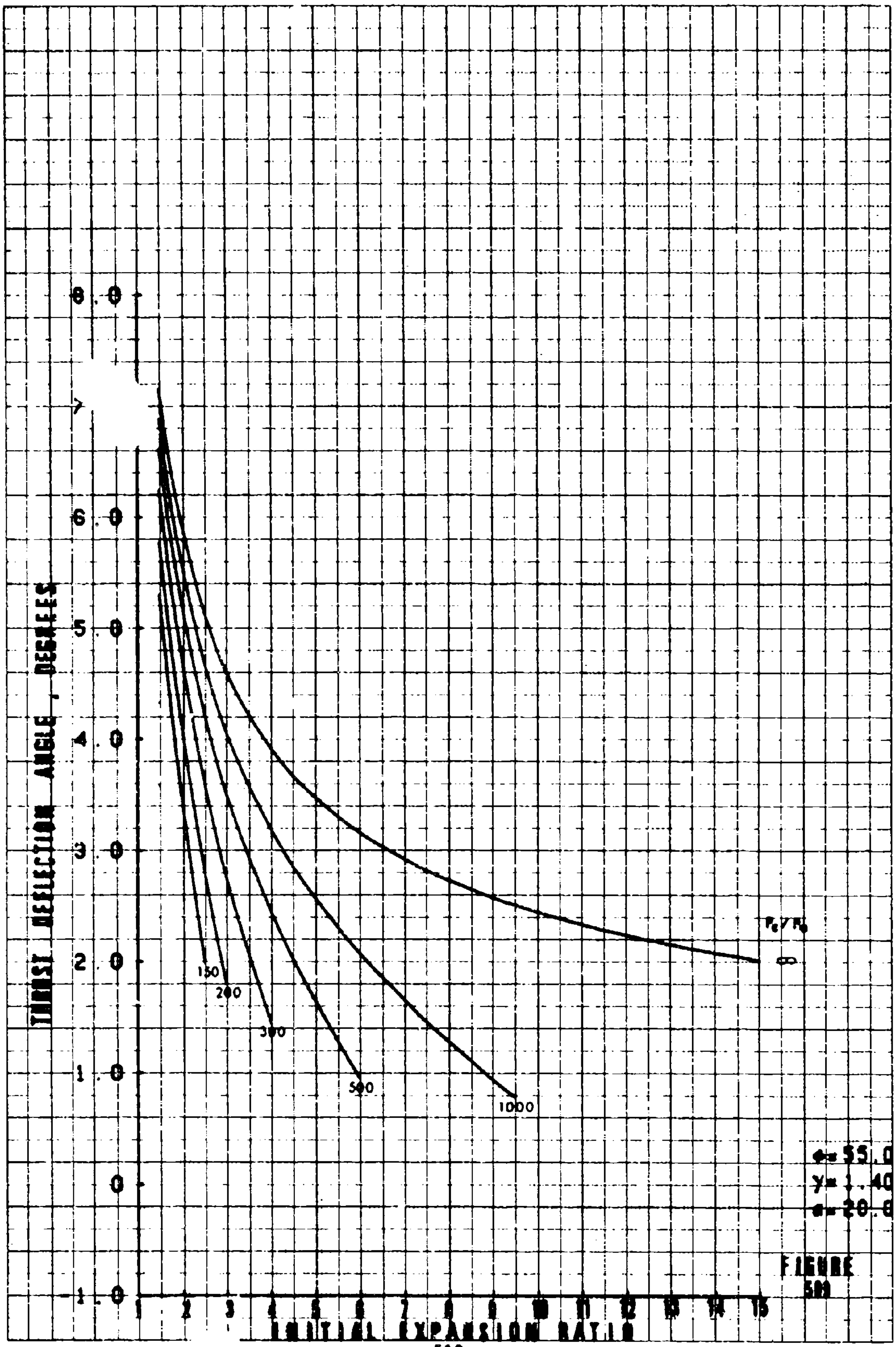
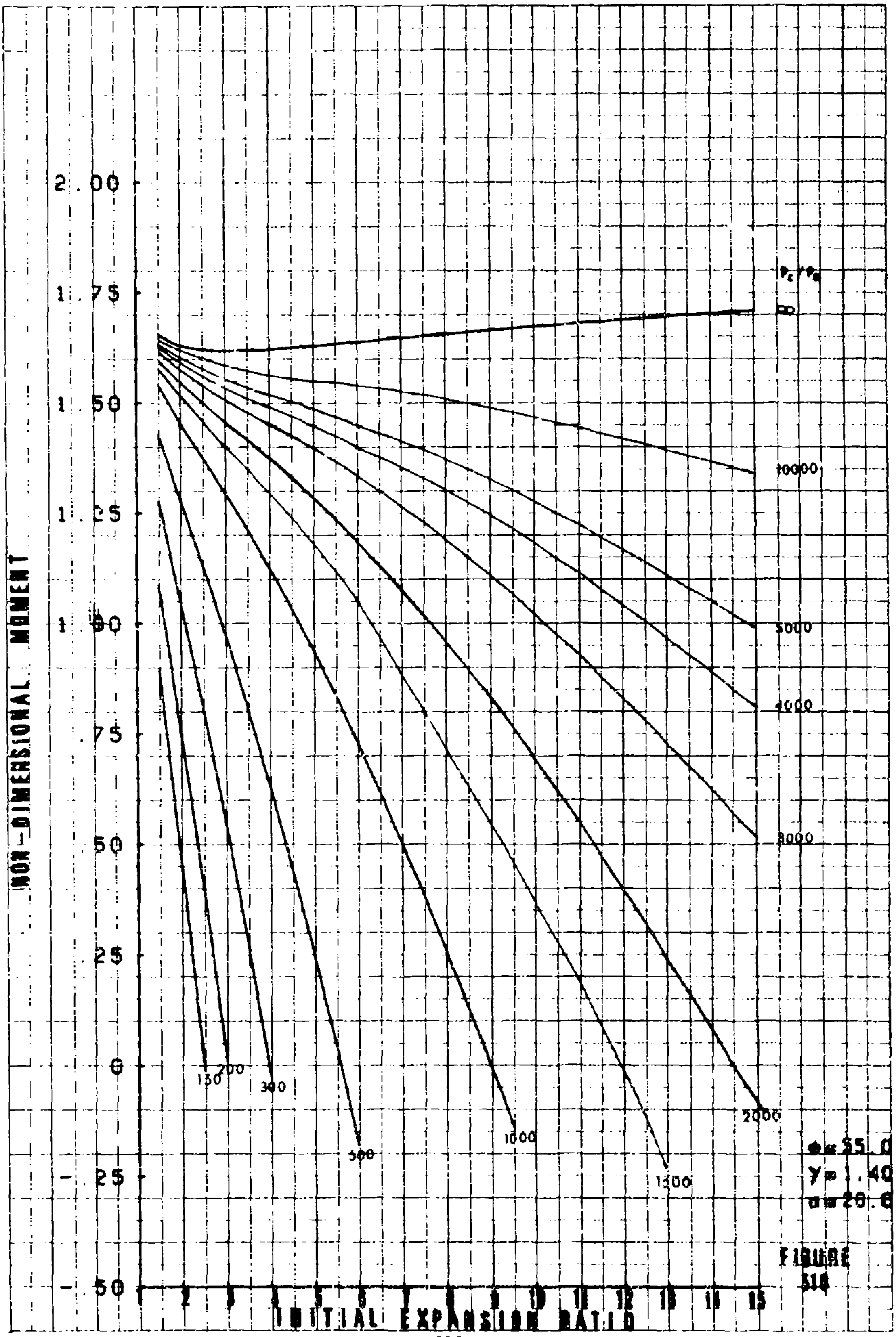

1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
THRUST COEFFICIENT
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
P_c/P_a
∞
1000
500
300
200
150
φ = 55.0
γ = 1.40
α = 20.0

FIGURE 508


THRUST DEFLECTION ANGLE, DEGREES
8.0
7
6.0
5.0
4.0
3.0
2.0
1.0
0
-1.0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
INITIAL EXPANSION RATIO
150
200
300
500
1000
∞
F_e/F_o
ϕ = 55.0
γ = 1.40
α = 20.0
FIGURE
509


NON-DIMENSIONAL MOMENT
INITIAL EXPANSION RATIO
2.00
1.75
1.50
1.25
1.00
.75
.50
.25
0
-.25
-.50
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
∞
10000
5000
4000
3000
2000
1500
1000
500
300
200
150
γ = 1.40
FIGURE

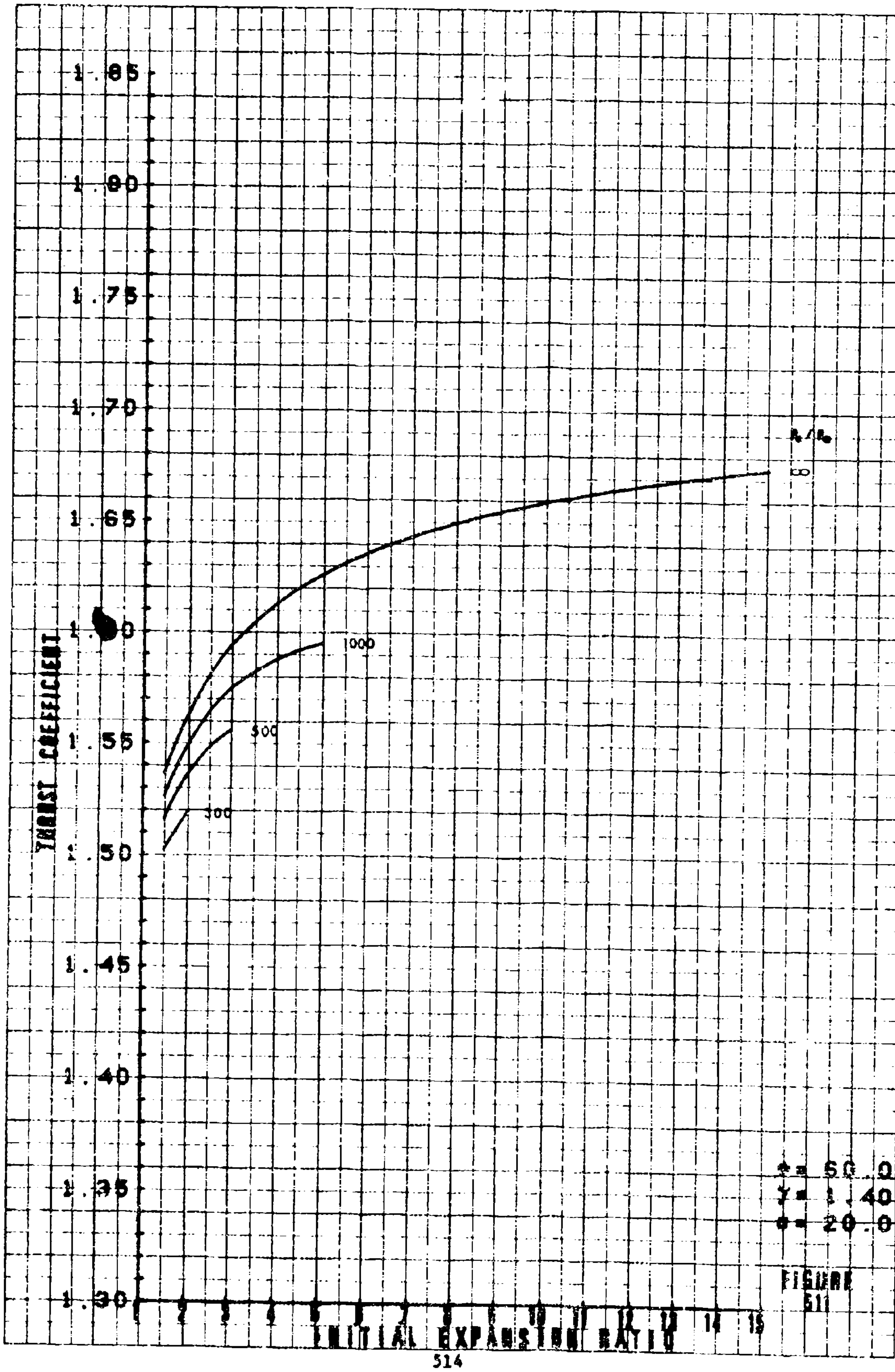

THRUST COEFFICIENT
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
INITIAL EXPANSION RATIO
1000
500
300
∞
φ = 60.0
γ = 1.40
θ = 20.0

FIGURE 511

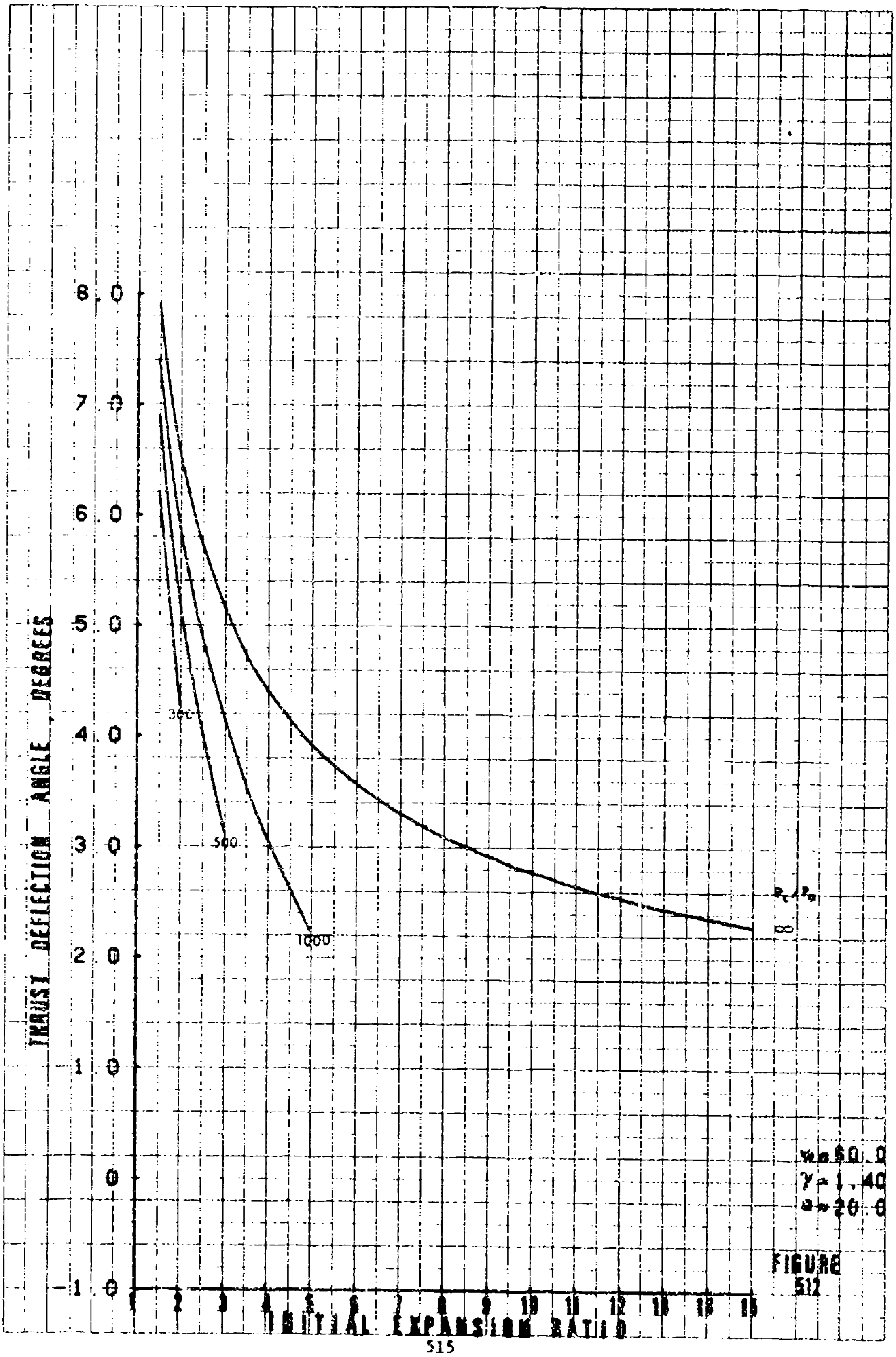
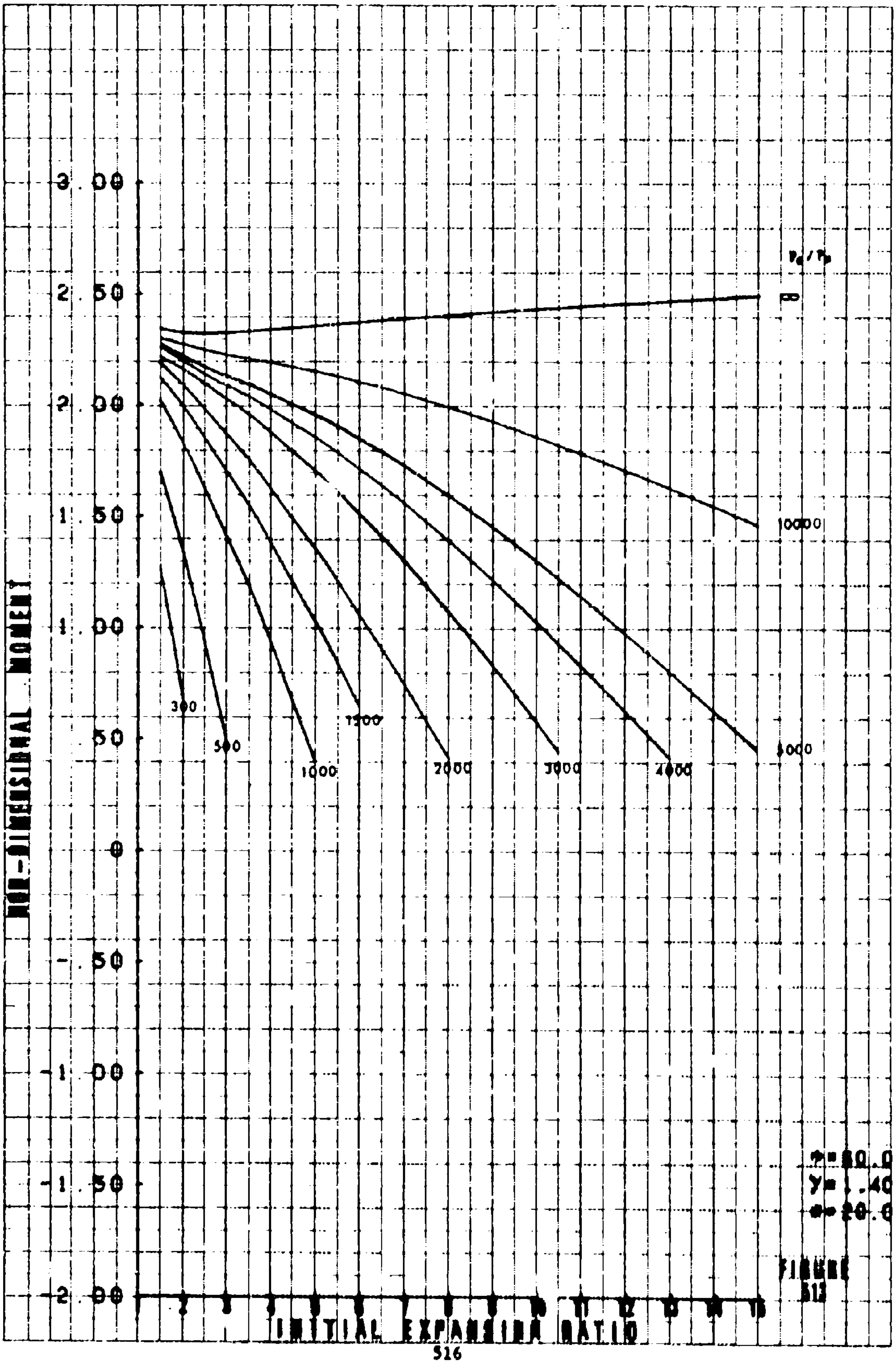

THRUST DEFLECTION ANGLE , DEGREES
INITIAL EXPANSION RATIO
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
-1.0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
300
500
1000
P_c/P_a
∞
$\gamma = 1.40$
α = 20.0

FIGURE 512



3.00
2.50
2.00
1.50
1.00
.50
0
-.50
-1.00
-1.50
-2.00
NON-DIMENSIONAL MOMENT
INITIAL EXPANSION RATIO
300
500
1000
1500
2000
3000
4000
5000
10000
∞

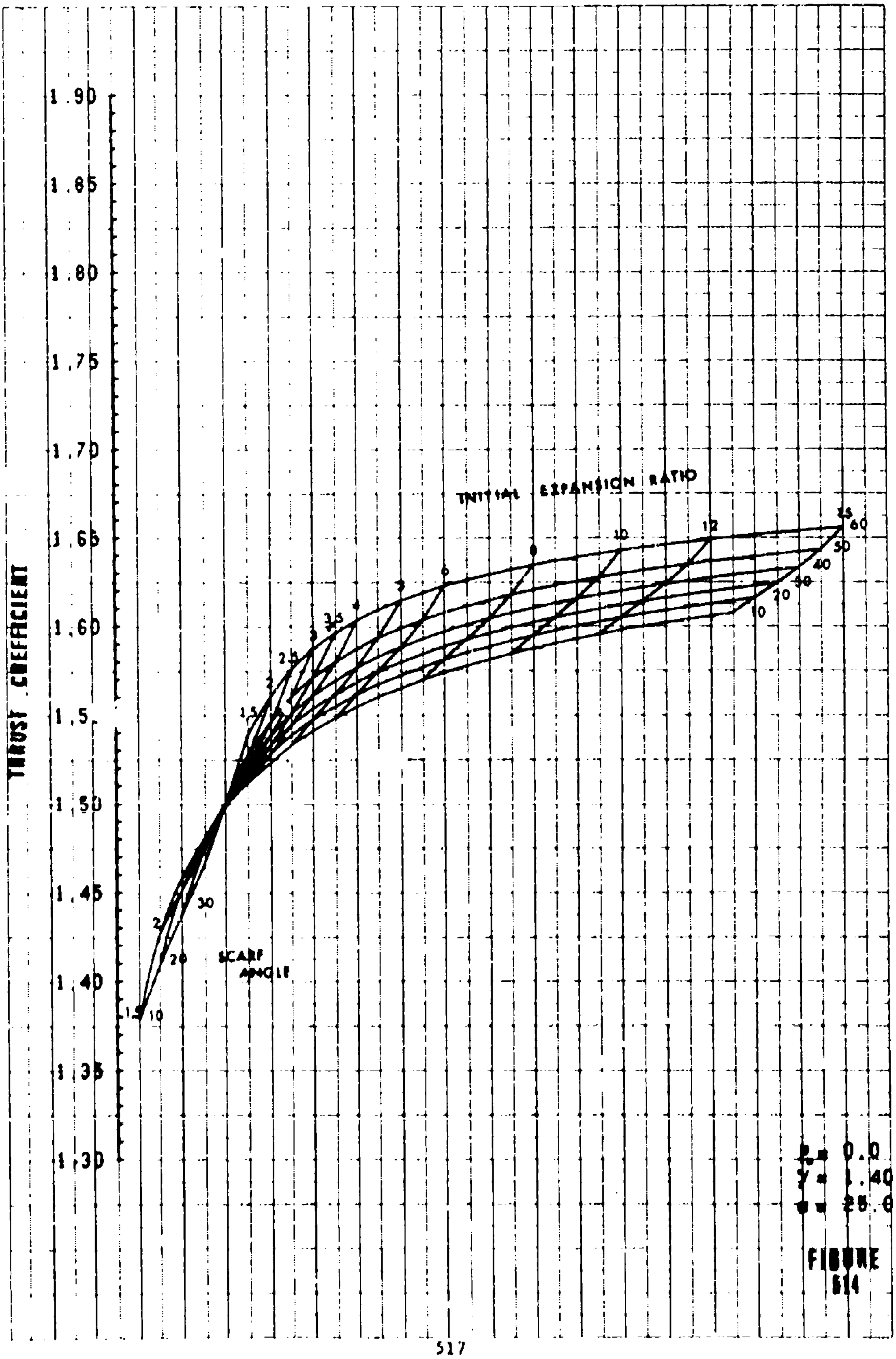
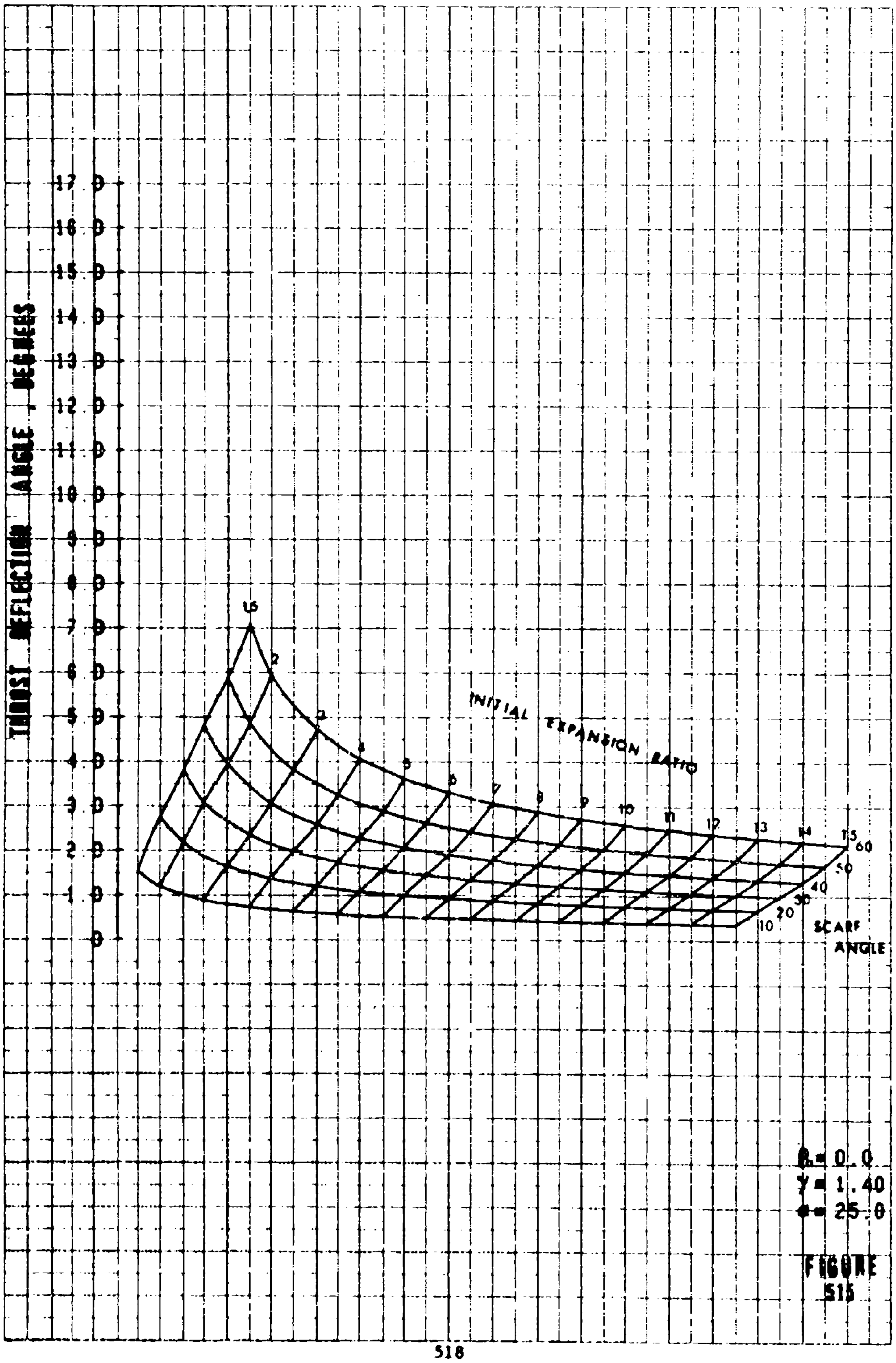

THRUST COEFFICIENT
1.90
1.85
1.80
1.75
1.70
1.65
1.60
1.50
1.45
1.40
1.35
1.30
INITIAL EXPANSION RATIO
SCARF ANGLE

FIGURE 514



$R_c = 0.0$
$\gamma = 1.40$
$\theta = 25.0$

FIGURE 515

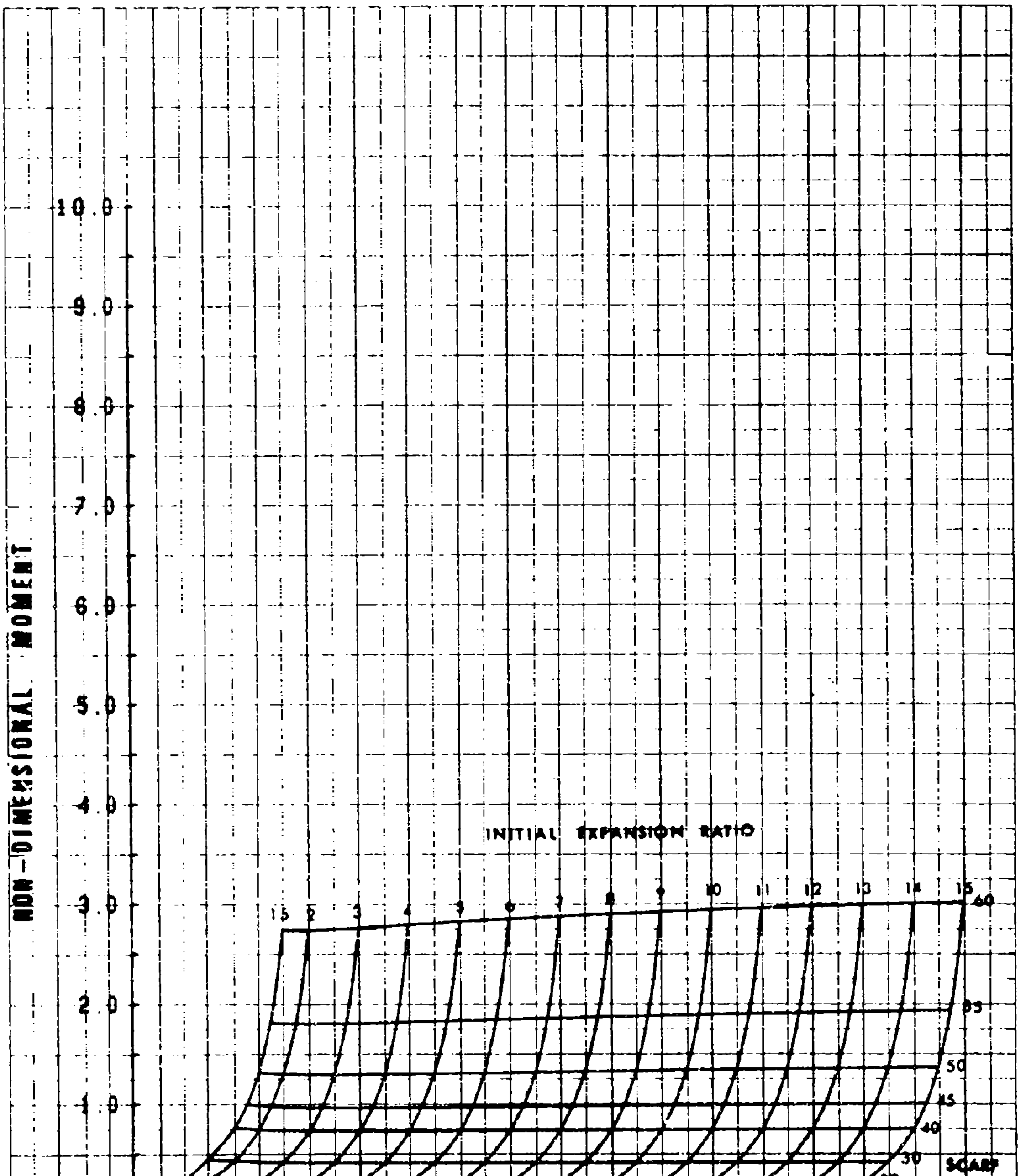
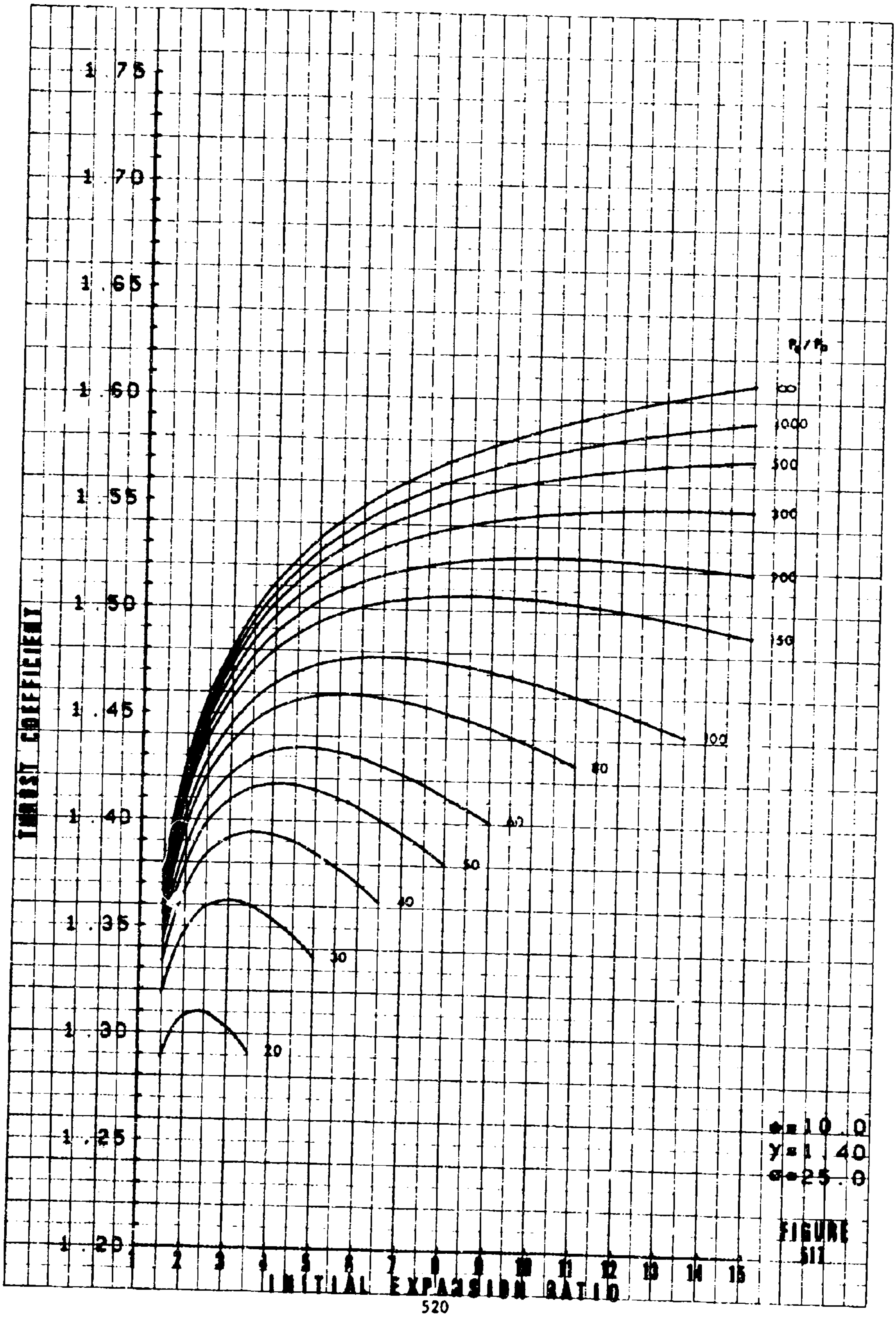
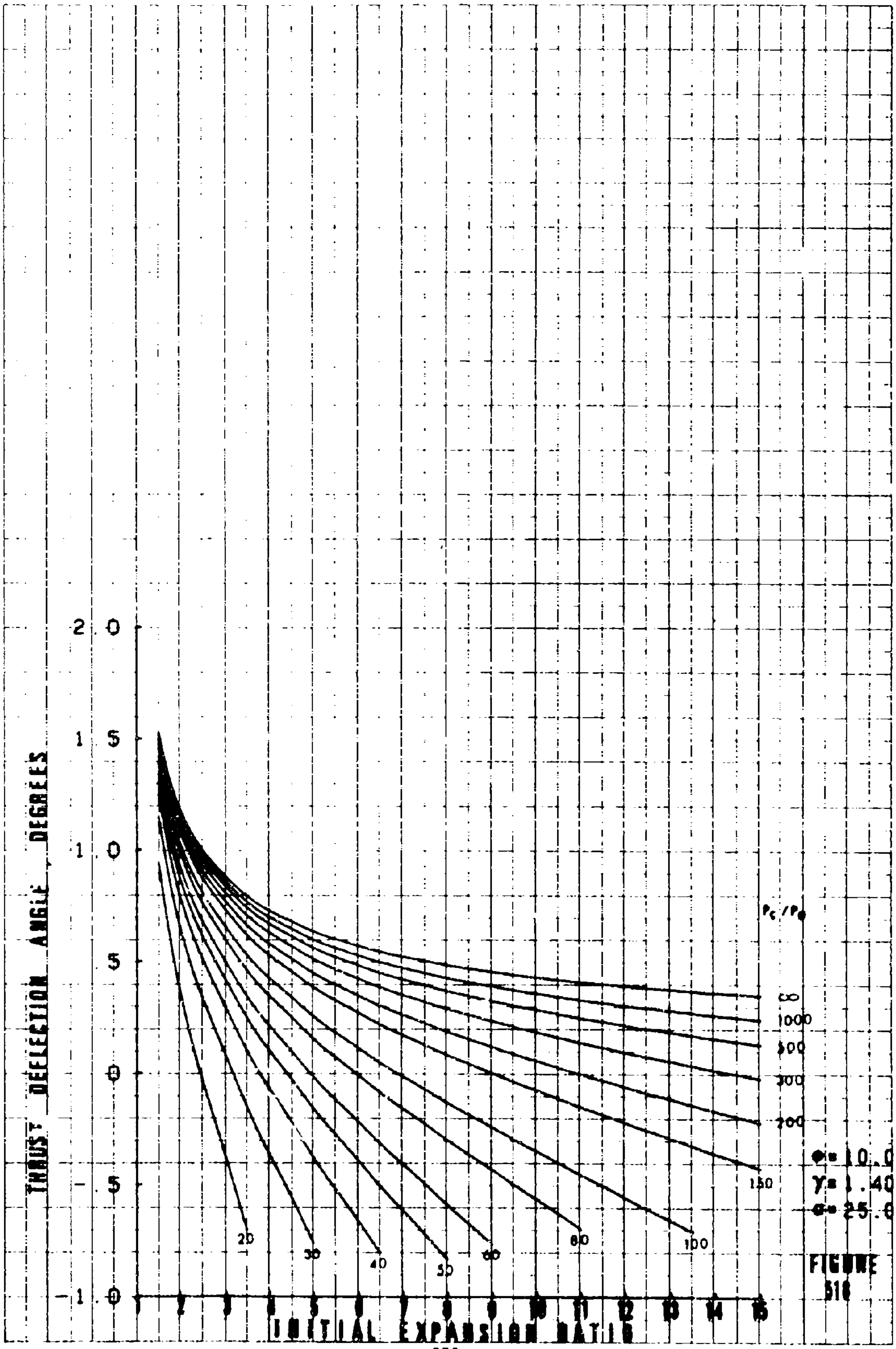

NON-DIMENSIONAL MOMENT
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
INITIAL EXPANSION RATIO
1.5 2 3 4 5 6 7 8 9 10 11 12 13 14 15
60
55
50
45
40
30
20
0
SCARF ANGLE
P_a= 0.0
γ= 1.40
α= 25.0

FIGURE 518


THRUST COEFFICIENT
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
1.25
1.20
INITIAL EXPANSION RATIO
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
P_c/P_a
∞
1000
500
300
200
150
100
80
60
50
40
30
20
ε=10.0
γ=1.40
α=25.0
FIGURE 511



THRUST DEFLECTION ANGLE, DEGREES
2.0
1.5
1.0
.5
0
-.5
-1.0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
INITIAL EXPANSION RATIO
P_c/P_e
∞
1000
500
300
200
150
100
80
60
50
40
30
20
φ= 10.0
γ= 1.40
FIGURE

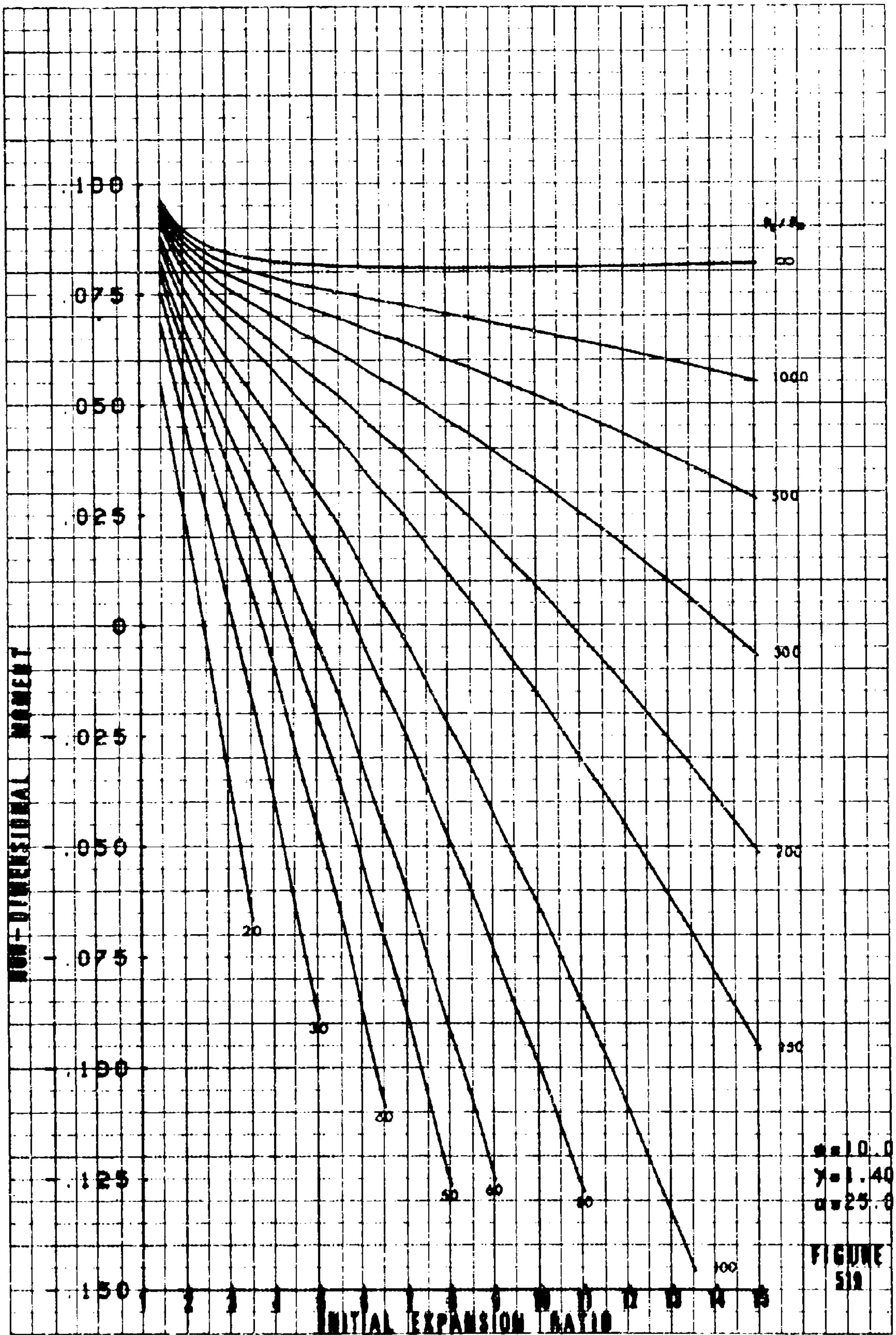

NON-DIMENSIONAL MOMENT
INITIAL EXPANSION RATIO
.100
.075
.050
.025
0
-.025
-.050
-.075
-.100
-.125
-.150
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
∞
1000
500
300
200
150
100
80
60
50
40
30
20

FIGURE 519

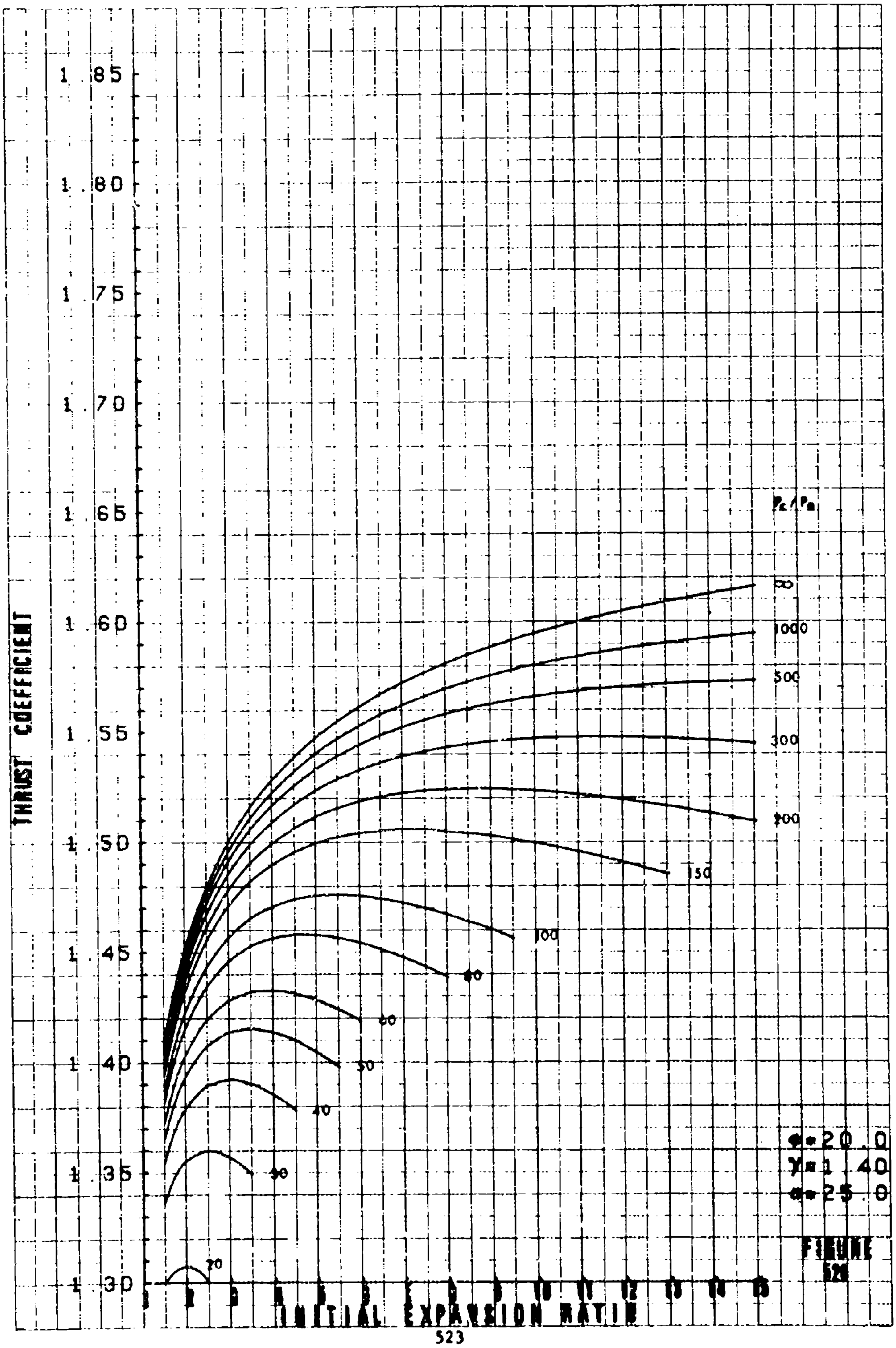
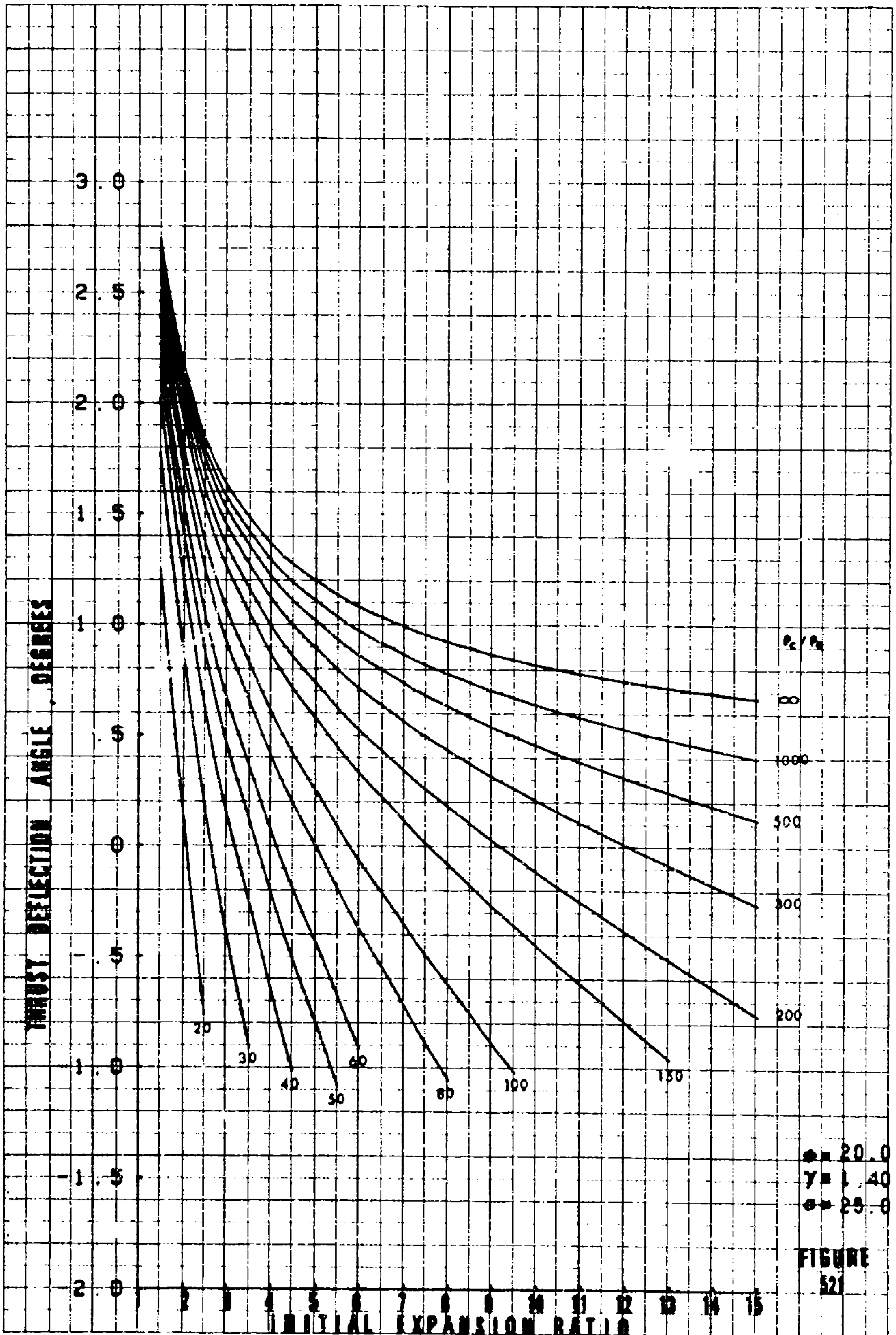
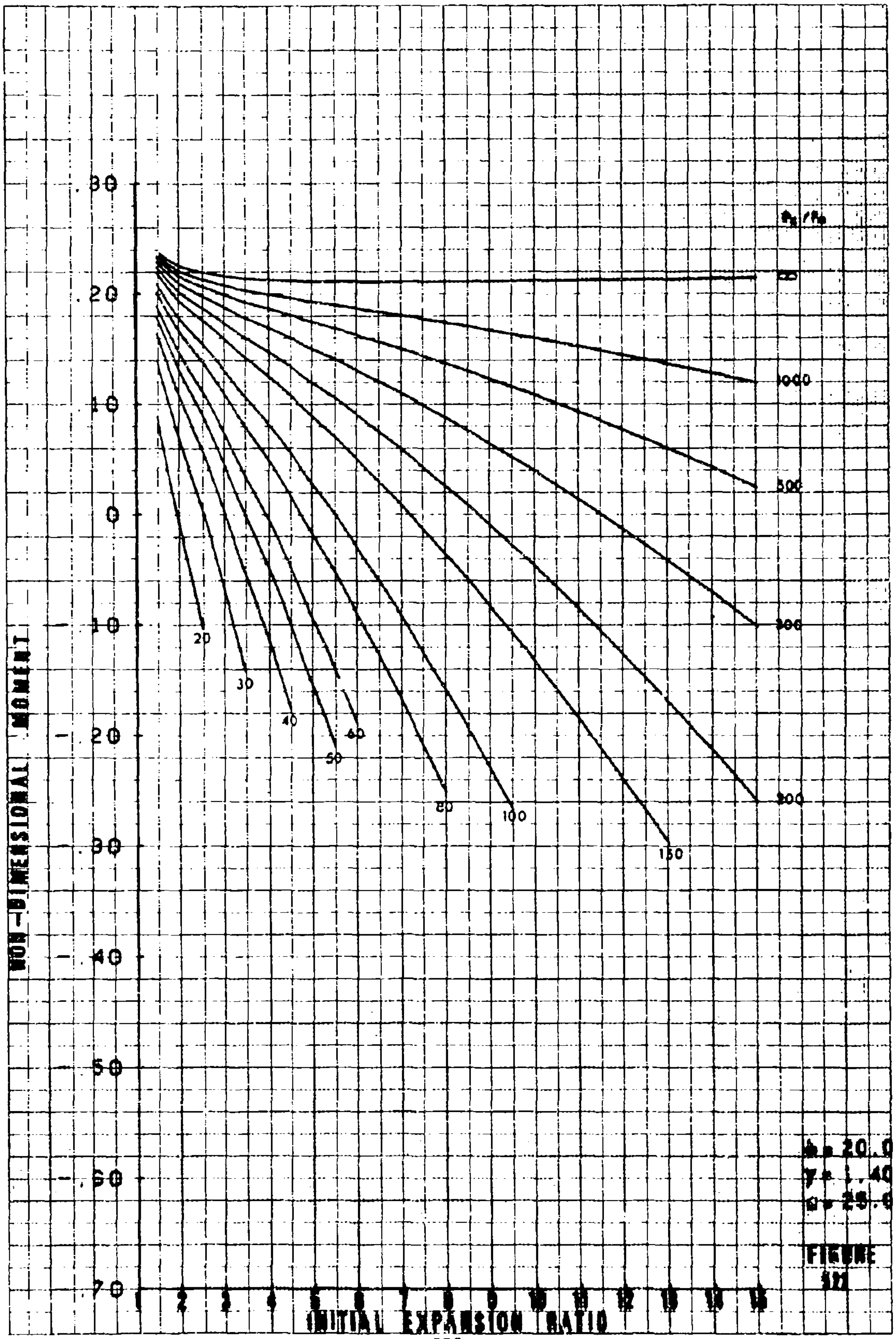

THRUST COEFFICIENT
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
INITIAL EXPANSION RATIO
P_c/P_a
∞
1000
500
300
200
150
100
80
60
50
40
30
20
φ=20.0
γ=1.40
α=25.0

FIGURE 528



THRUST DEFLECTION ANGLE, DEGREES
INITIAL EXPANSION RATIO
P_c/P_a
∞
1000
500
300
200
150
100
80
60
50
40
30
20
3.0
2.5
2.0
1.5
1.0
.5
0
-.5
-1.0
-1.5
-2.0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
ϕ = 20.0
γ = 1.40
σ = 25.0

FIGURE 521


NON-DIMENSIONAL MOMENT
INITIAL EXPANSION RATIO
.30
.20
.10
0
-.10
-.20
-.30
-.40
-.50
-.60
-.70
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
∞
1000
500
300
200
150
100
80
60
50
40
30
20
20.0
1.40
25.0
FIGURE

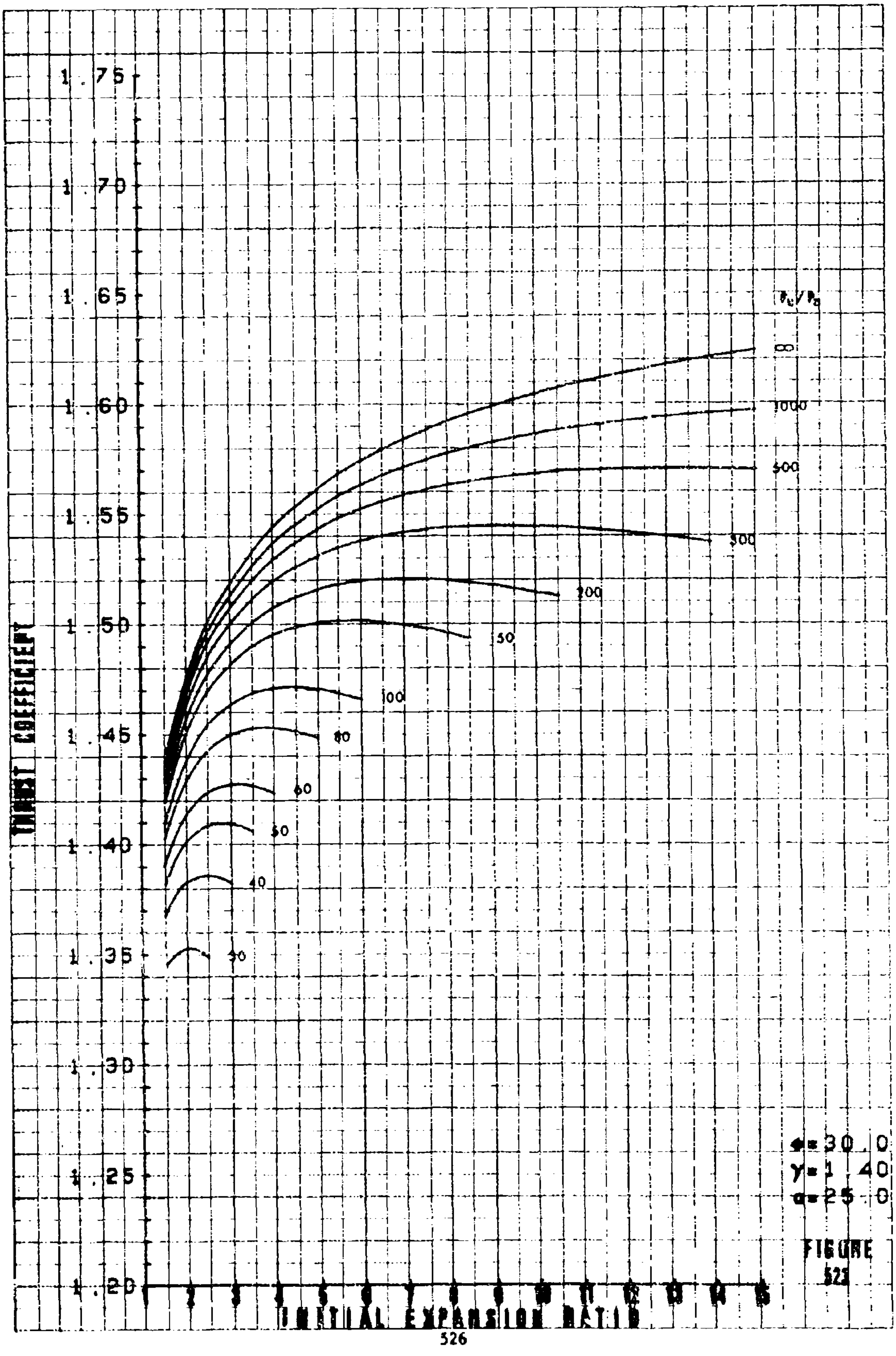

THRUST COEFFICIENT
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
1.25
1.20
INITIAL EXPANSION RATIO
P_c/P_a
∞
1000
500
300
200
150
100
80
60
50
40
30
ϕ= 30.0
γ= 1.40
α= 25.0

FIGURE 523

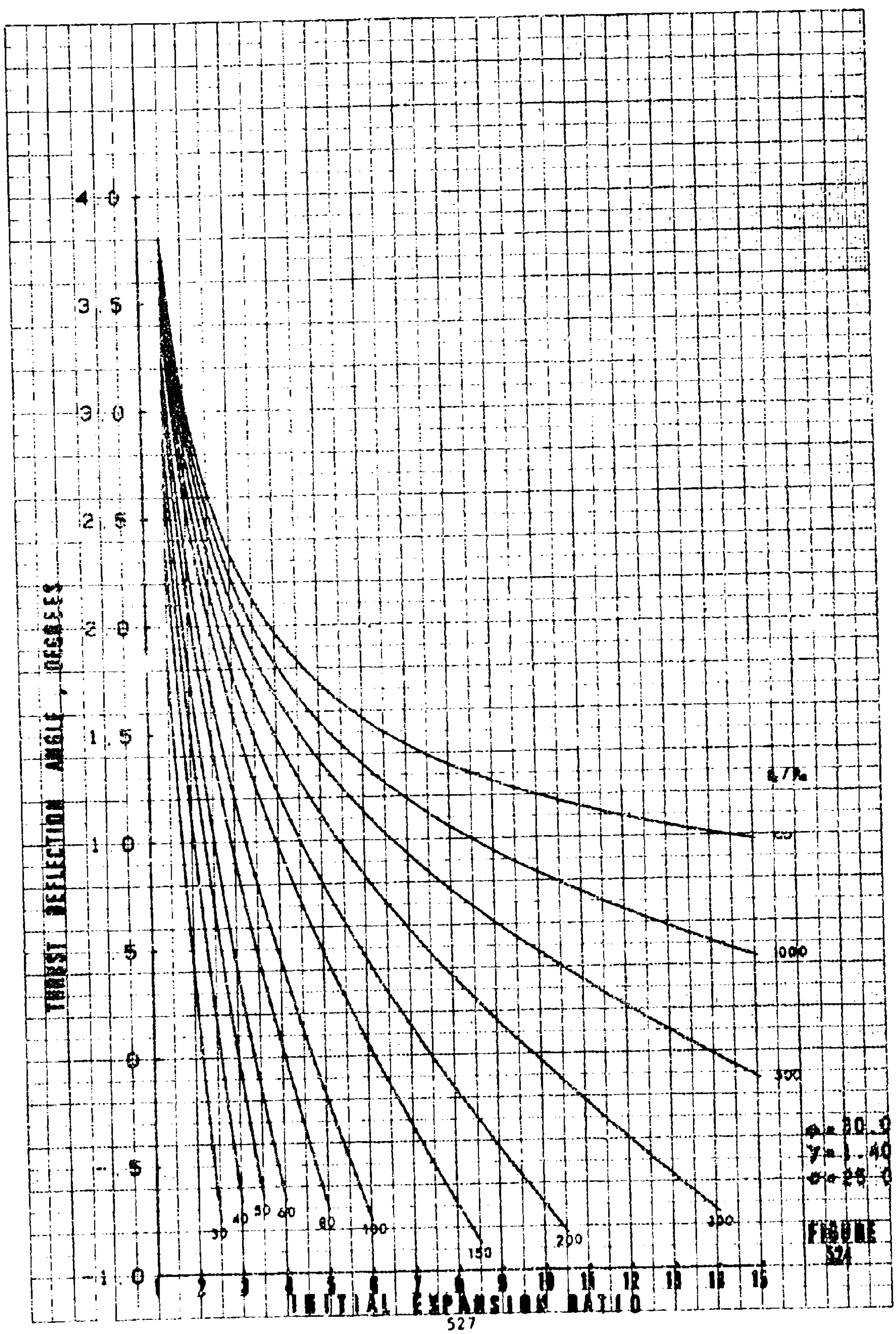
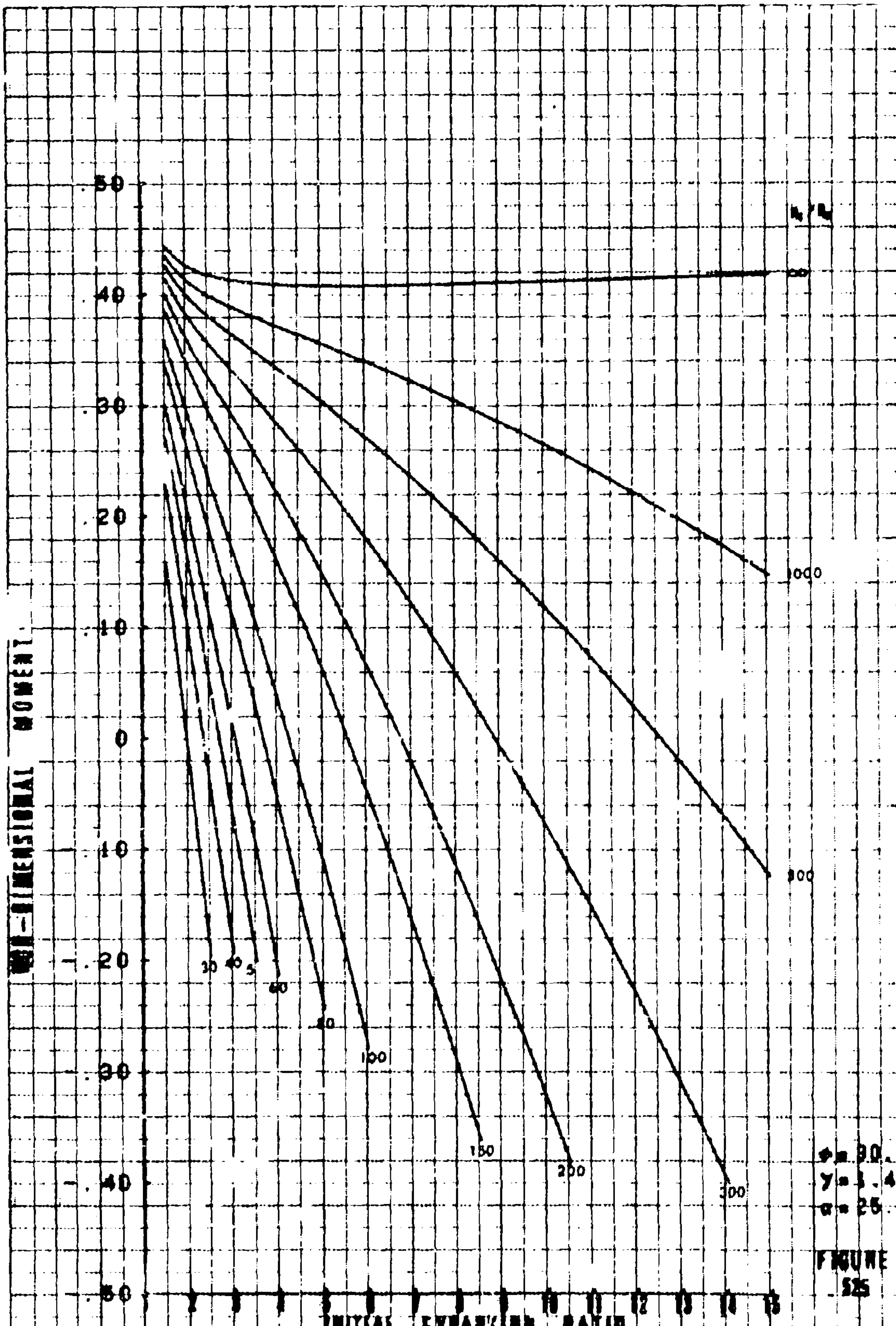
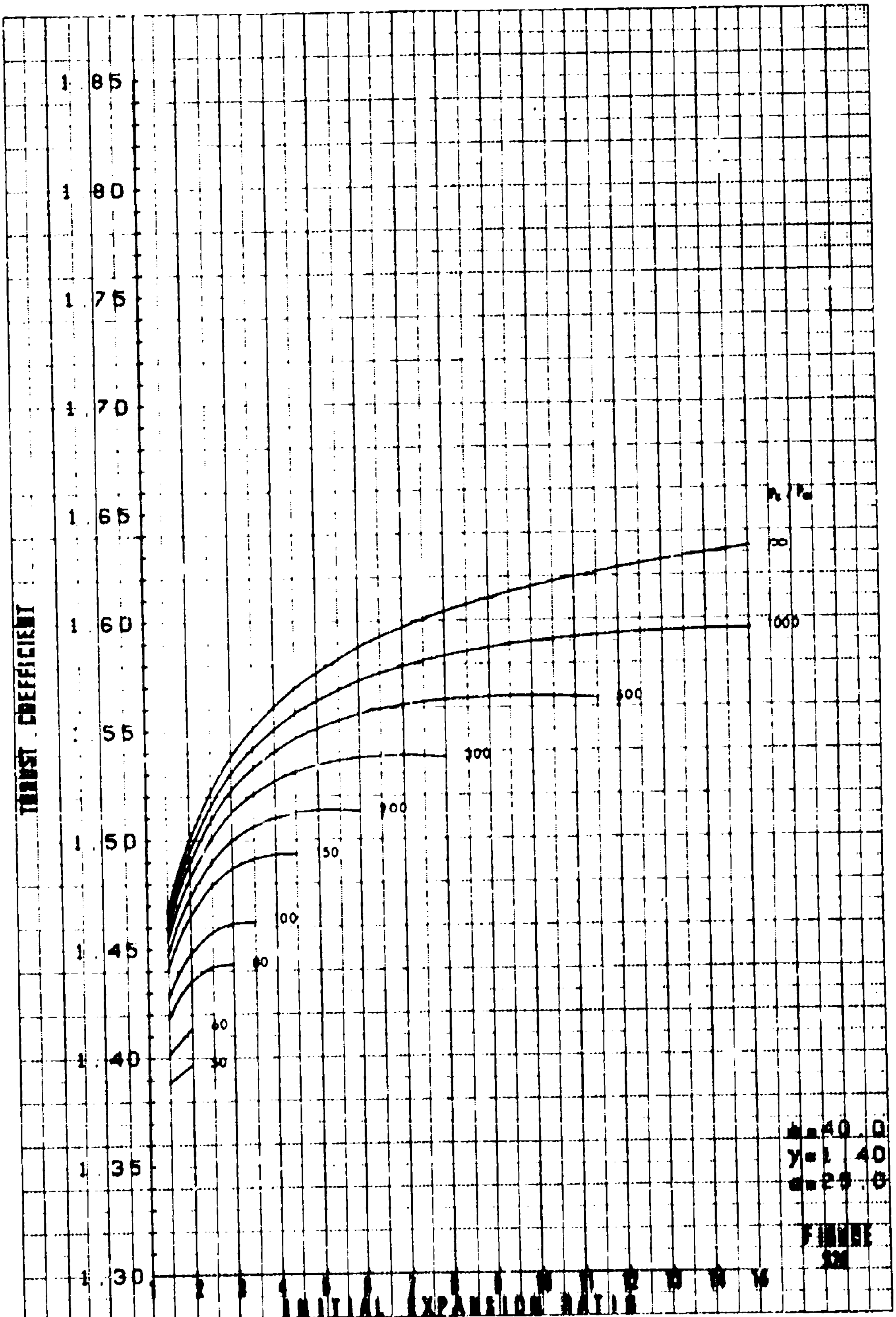
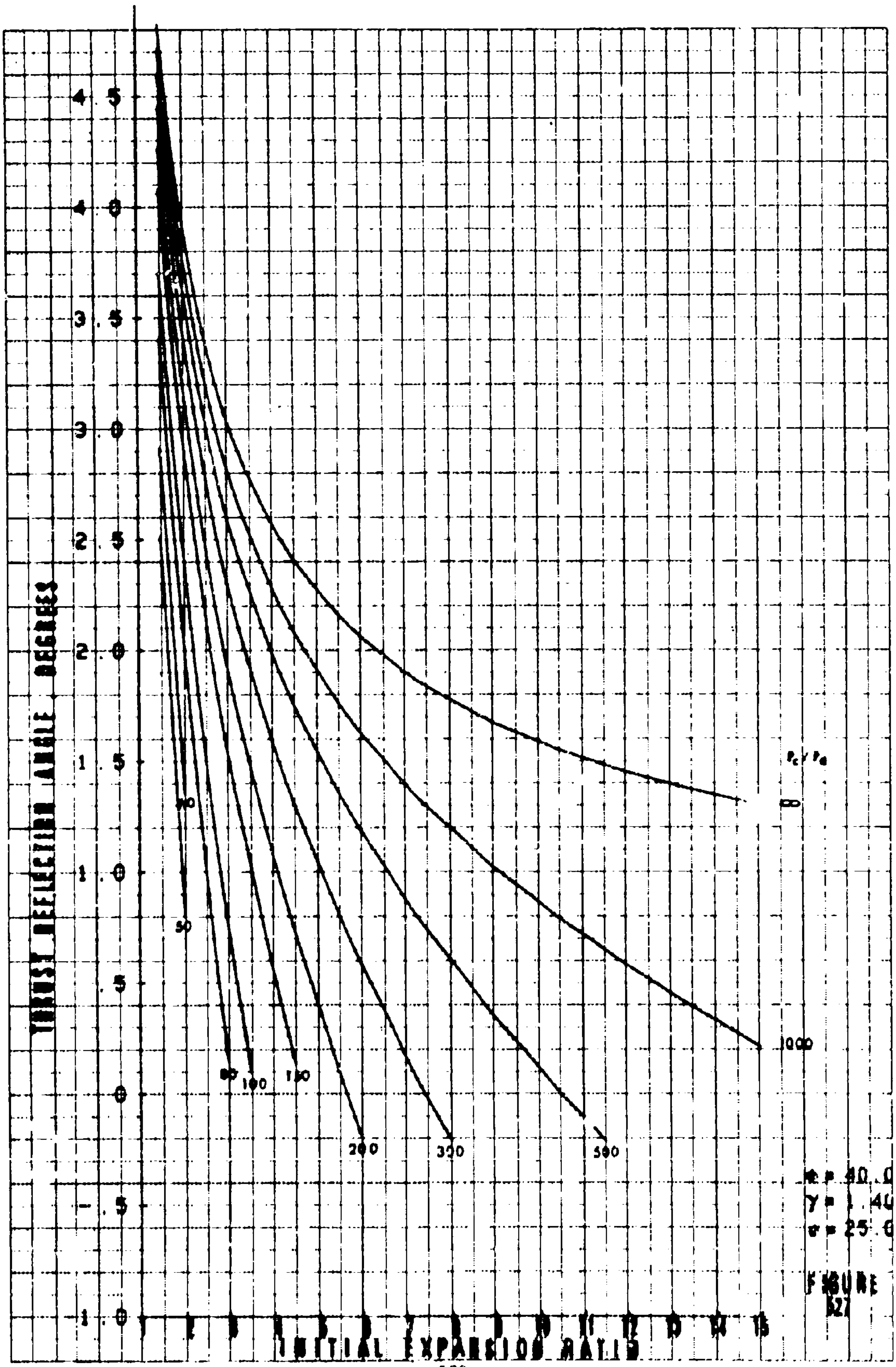

THRUST DEFLECTION ANGLE , DEGREES
INITIAL EXPANSION RATIO
δ/P_a
1000
500
300
200
150
100
80
60
50
40
30

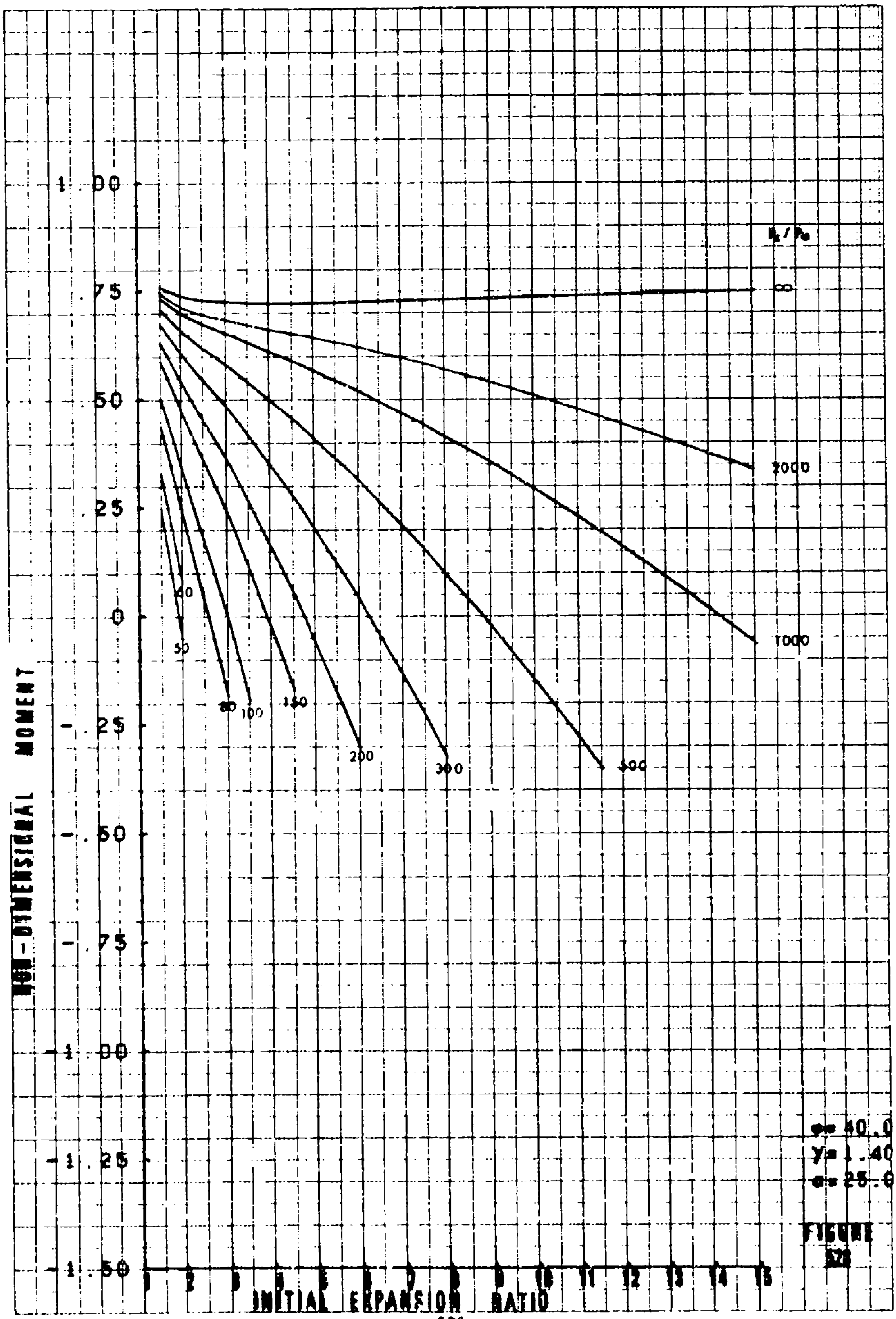
FIGURE 524

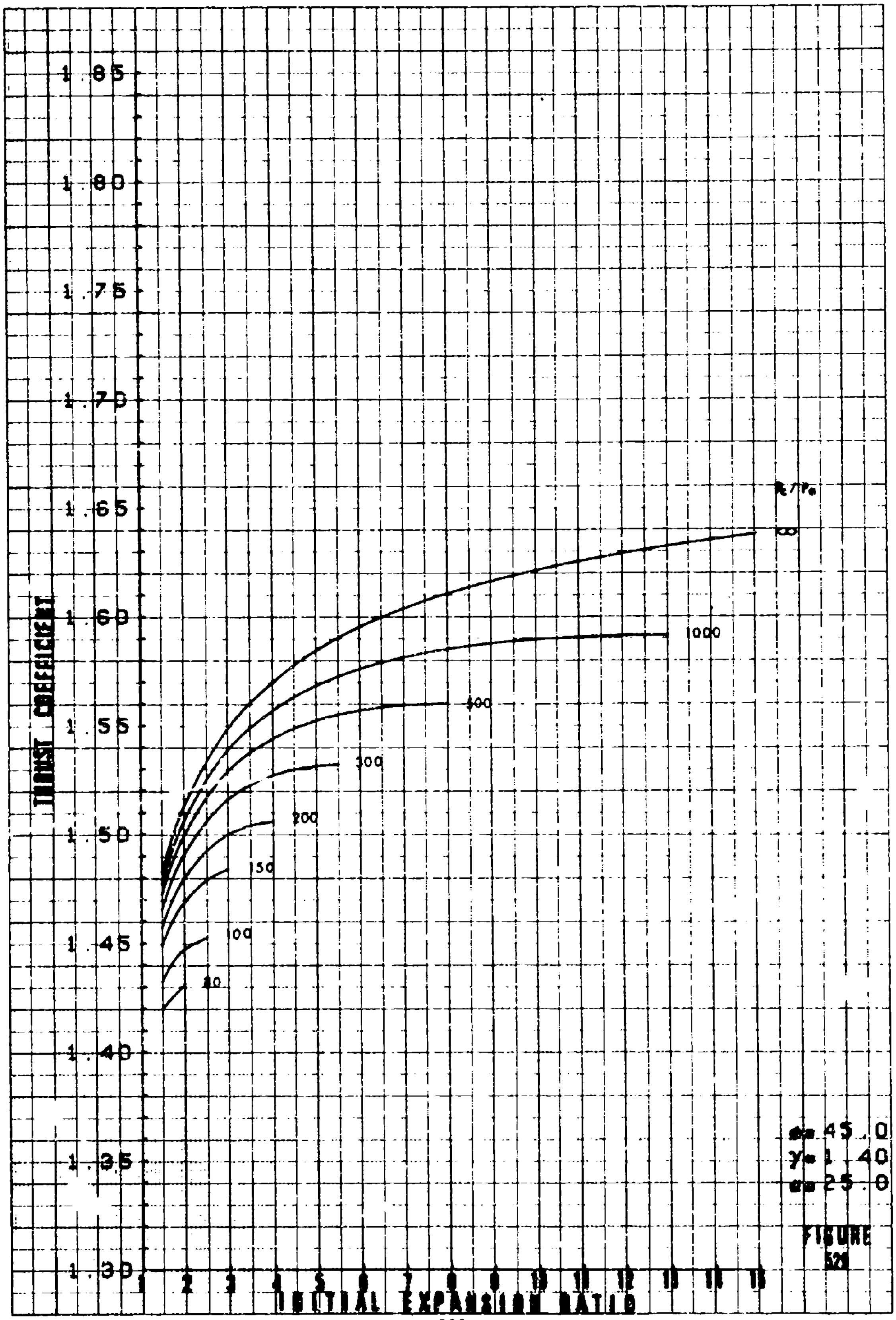

NON-DIMENSIONAL MOMENT
INITIAL EXPANSION RATIO
.50
.40
.30
.20
.10
0
-.10
-.20
-.30
-.40
-.50
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
1000
300
30
40
5
60
80
100
150
200
300
FIGURE
525



THRUST COEFFICIENT
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
∞
1000
500
300
200
150
100
80
60
50
γ=1.40
INITIAL EXPANSION RATIO

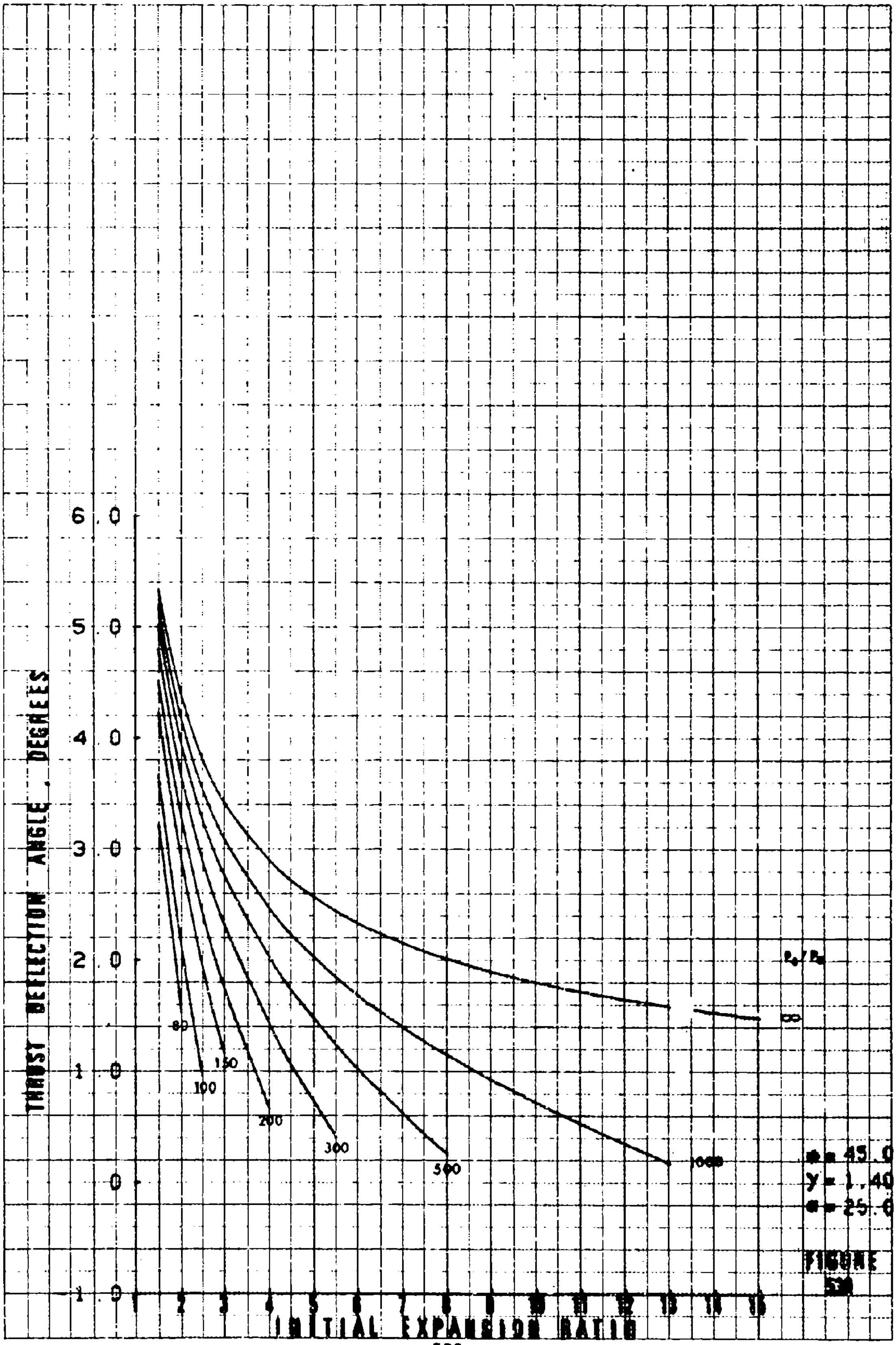

THRUST DEFLECTION ANGLE, DEGREES
INITIAL EXPANSION RATIO
P_c/P_a
∞
1000
500
300
200
150
100
80
50
ε = 40.0
γ = 1.40
σ = 25.0
FIGURE 527


NON-DIMENSIONAL MOMENT
INITIAL EXPANSION RATIO
1.00
.75
.50
.25
0
-.25
-.50
-.75
-1.00
-1.25
-1.50
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
∞
2000
1000
500
300
200
150
100
80
60
50
FIGURE



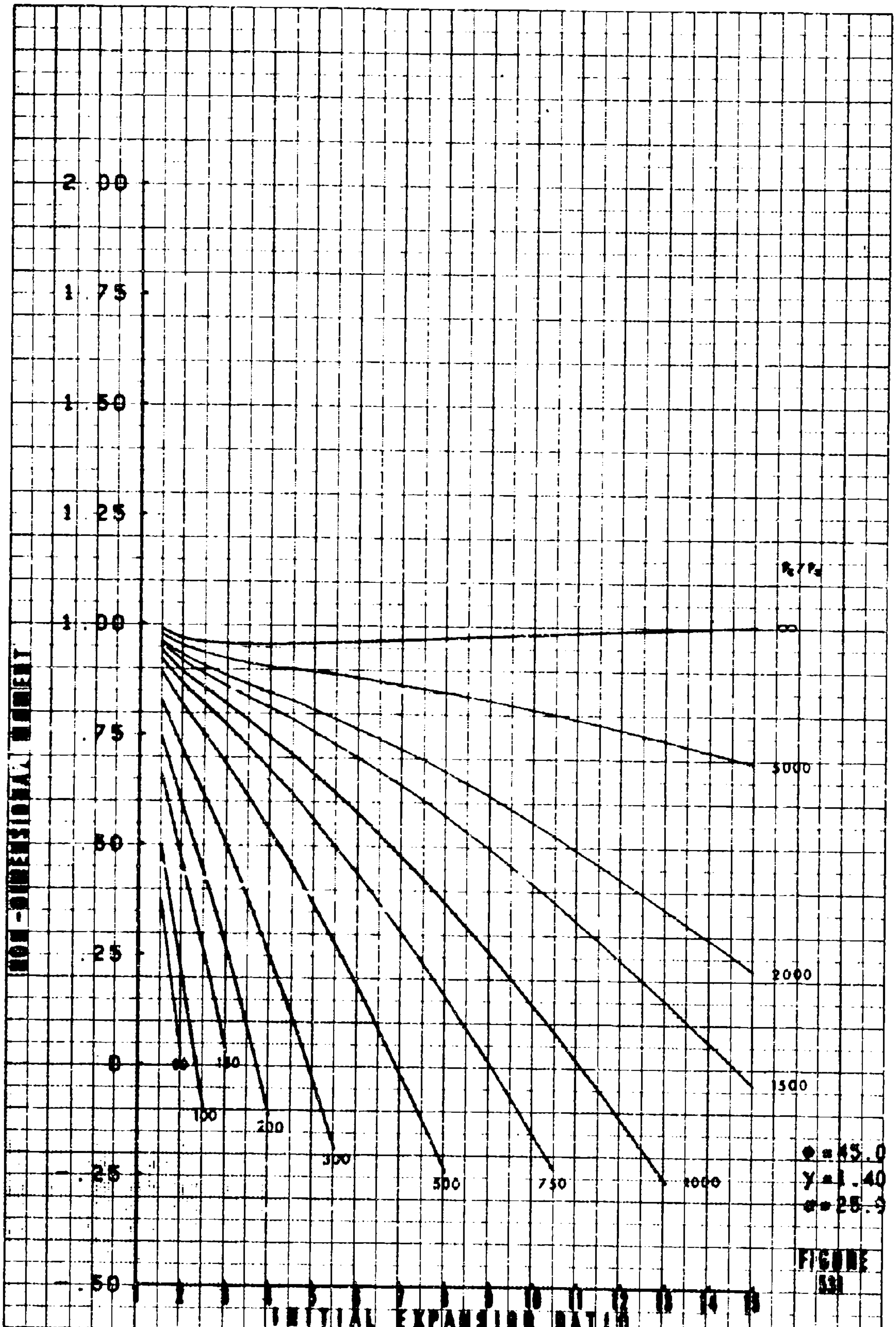
THRUST COEFFICIENT
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
P_c/P_a
∞
1000
500
300
200
150
100
80
α = 45.0
γ = 1.40
ϵ = 25.0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
INITIAL EXPANSION RATIO

FIGURE 529

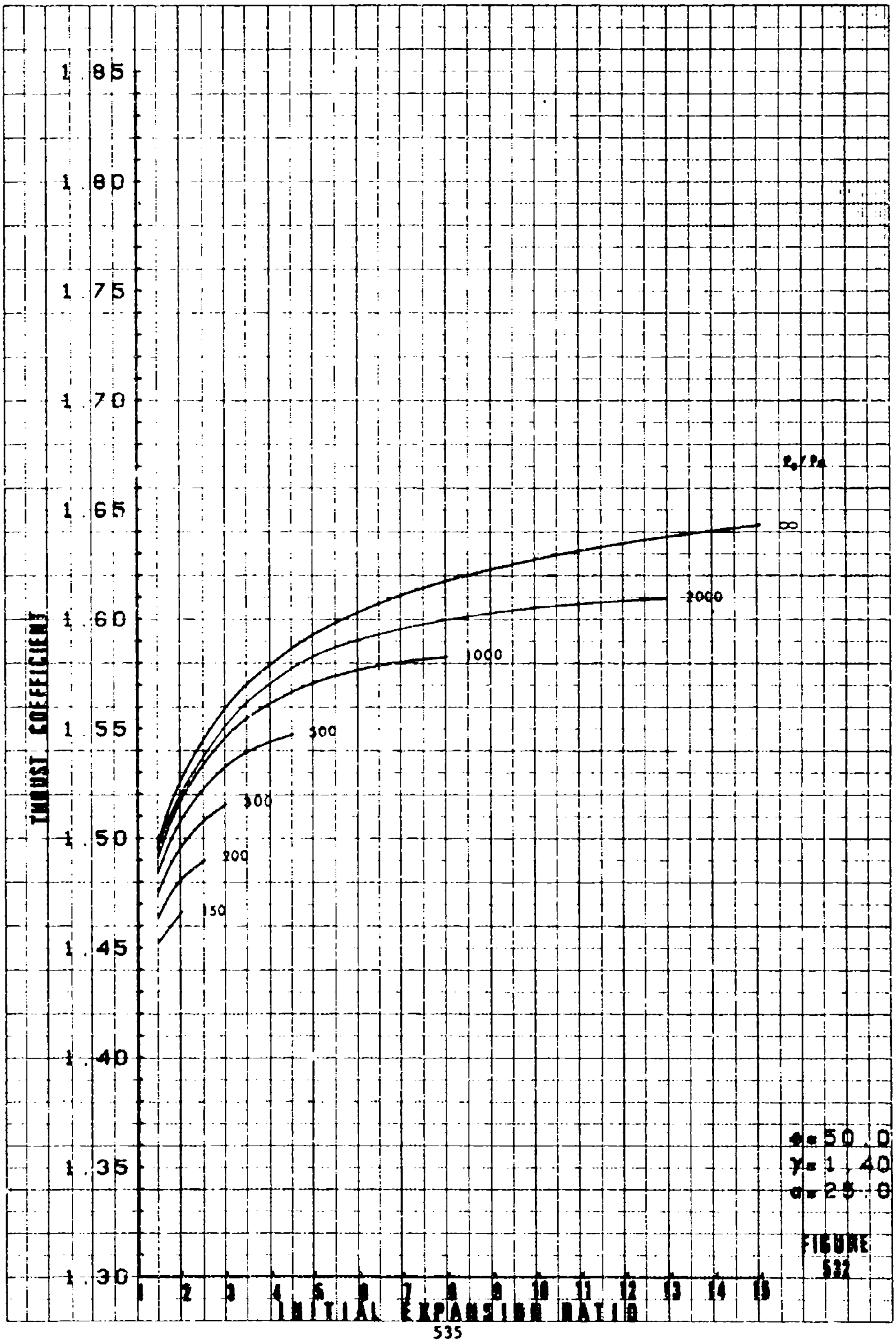


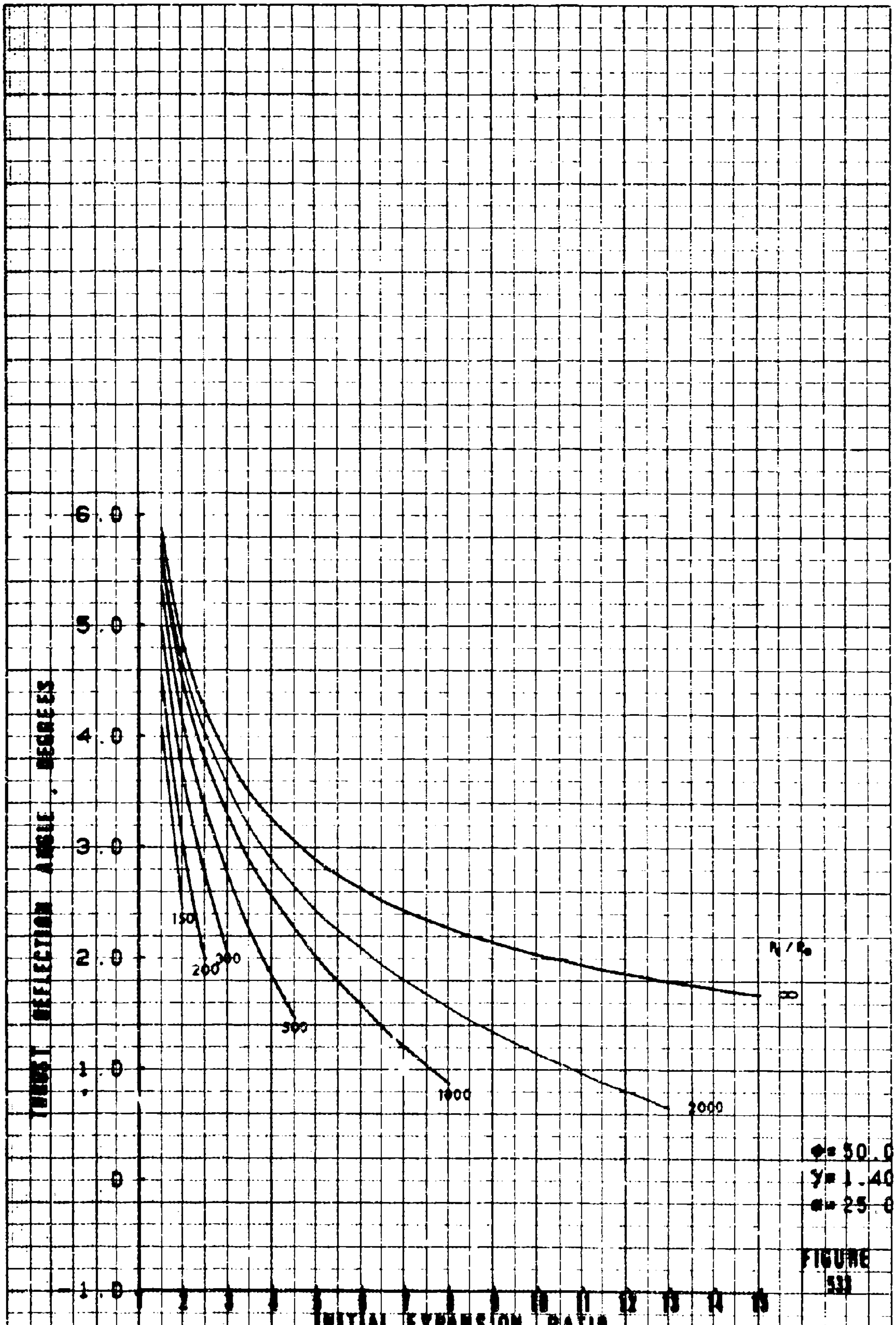
THRUST DEFLECTION ANGLE , DEGREES
INITIAL EXPANSION RATIO
6.0
5.0
4.0
3.0
2.0
1.0
0
-1.0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
80
100
150
200
300
500
1000
∞

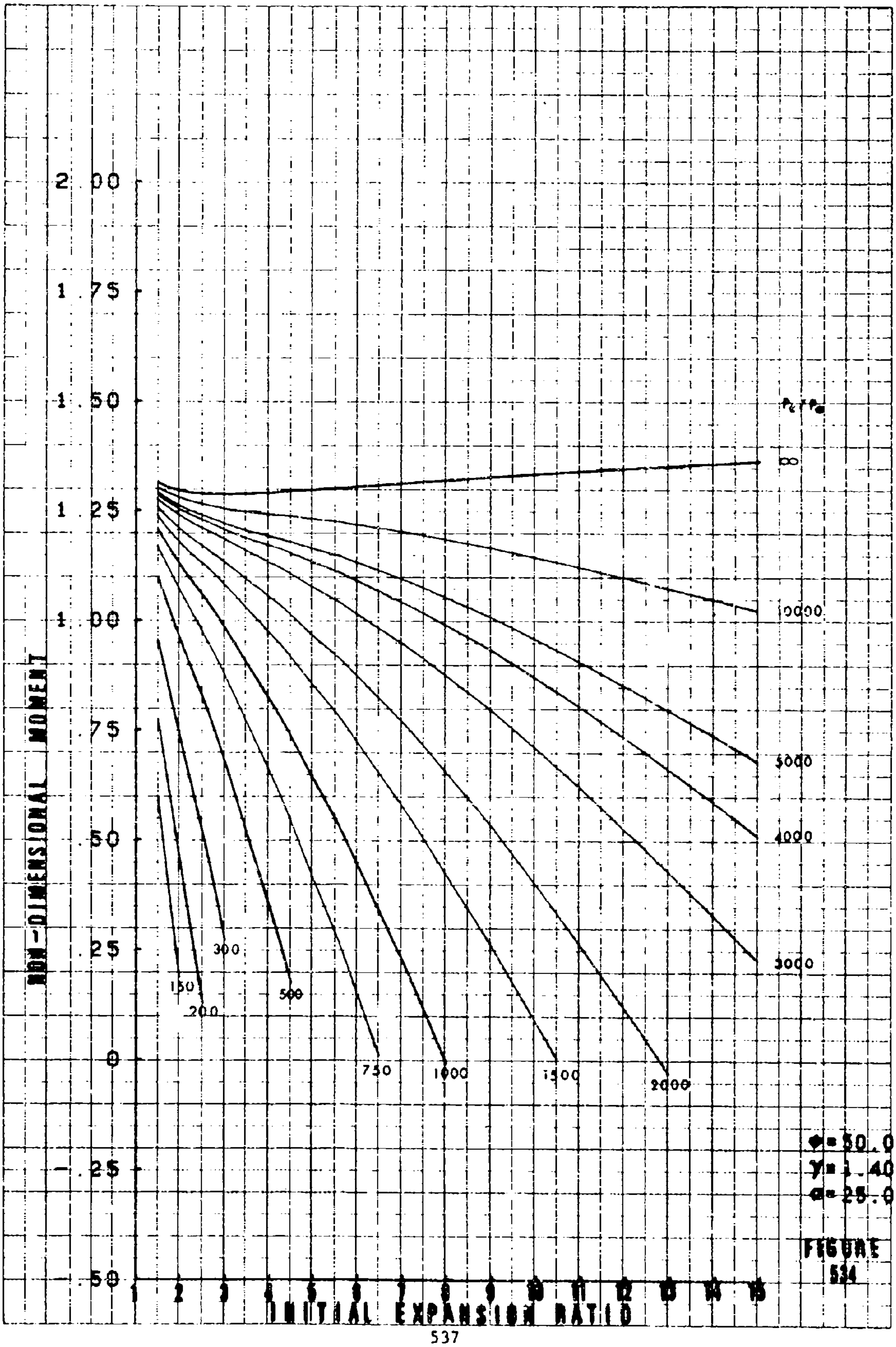
FIGURE 539

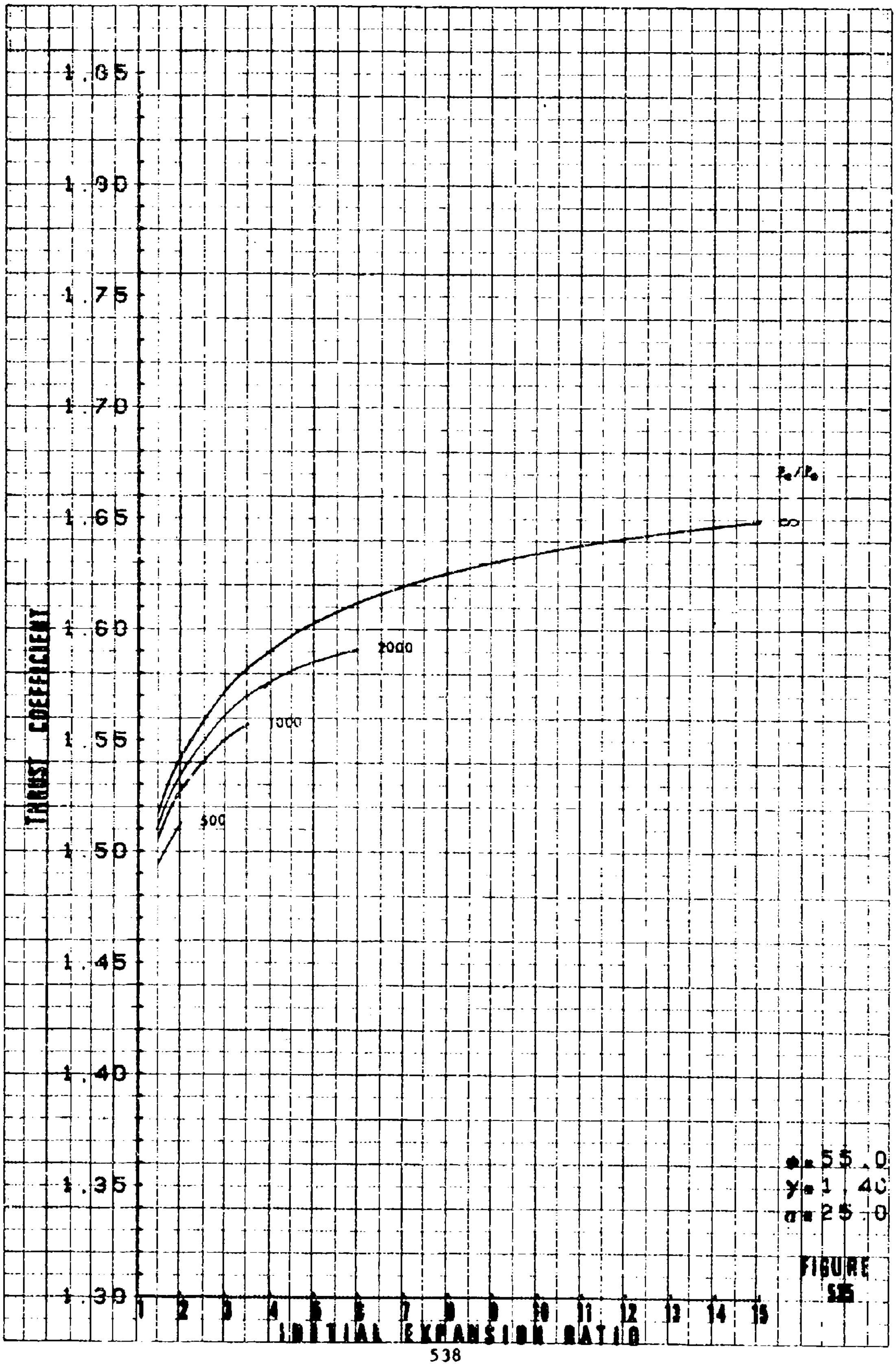


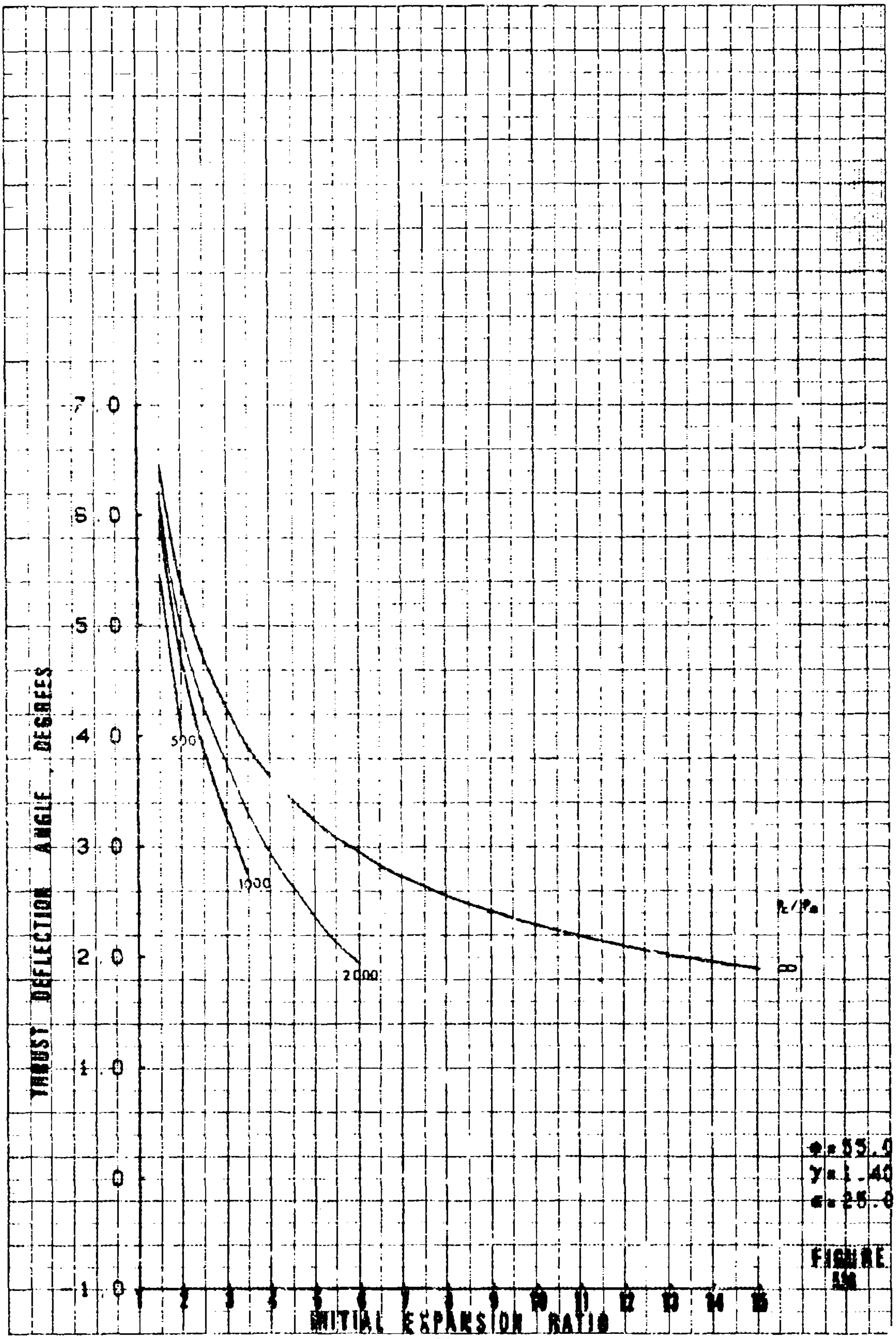
2.00
1.75
1.50
1.25
1.00
.75
.50
.25
0
-.25
-.50
NON-DIMENSIONAL MOMENT
INITIAL EXPANSION RATIO
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
∞
2000
1500
1000
750
500
300
200
150
100
FIGURE


THRUST COEFFICIENT
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
INITIAL EXPANSION RATIO
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
P_c/P_a
∞
2000
1000
500
300
200
150
= 50.0
γ = 1.40
α = 25.0
FIGURE 532

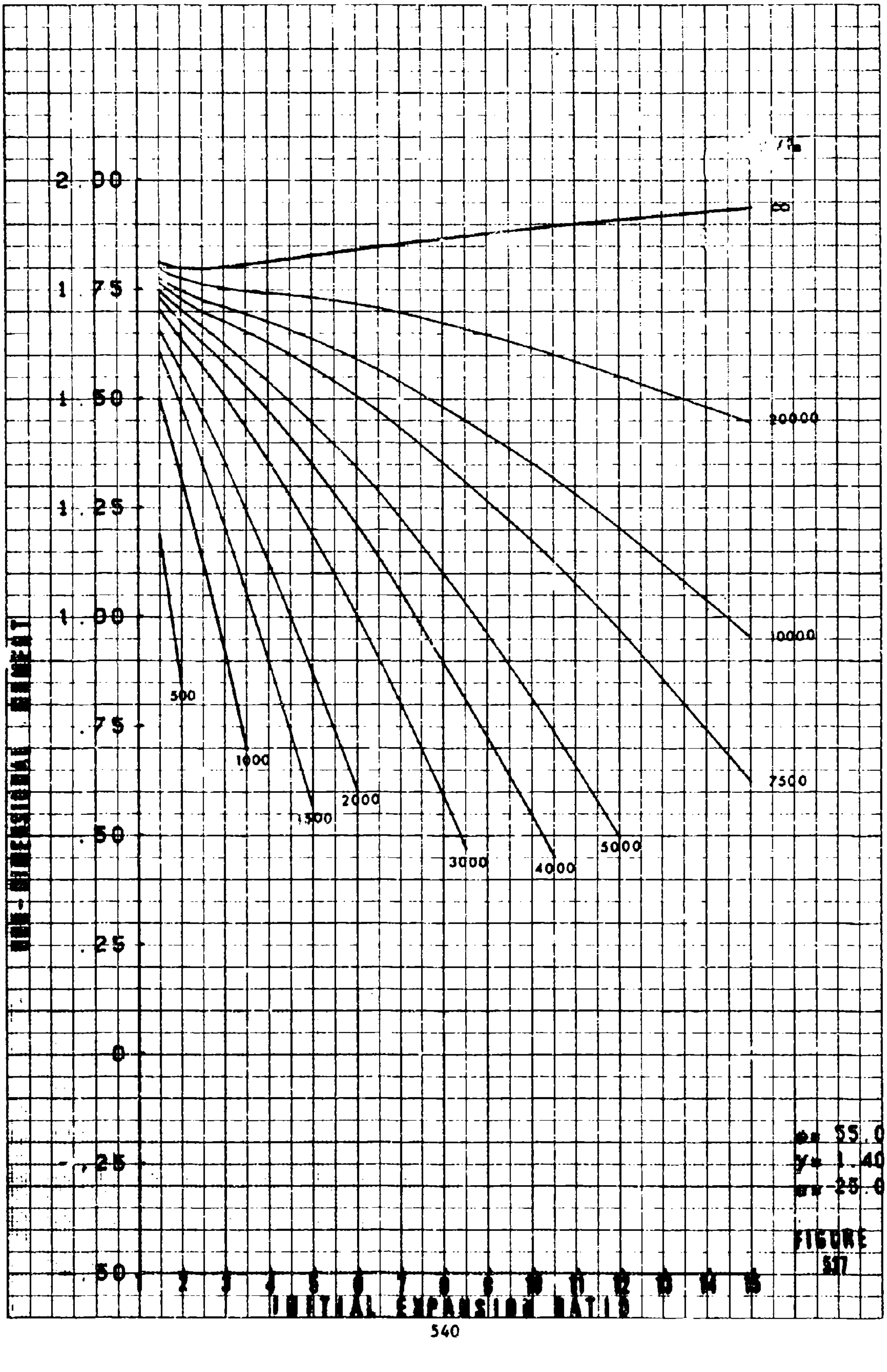

THRUST DEFLECTION ANGLE, DEGREES
INITIAL EXPANSION RATIO
6.0
5.0
4.0
3.0
2.0
1.0
0
-1.0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
150
200
300
500
1000
2000
∞
γ= 1.40
FIGURE 533


NON-DIMENSIONAL MOMENT
INITIAL EXPANSION RATIO
P_c/P_a
∞
10000
5000
4000
3000
2000
1500
1000
750
500
300
200
150
φ = 30.0
γ = 1.40
α = 25.0
FIGURE
534

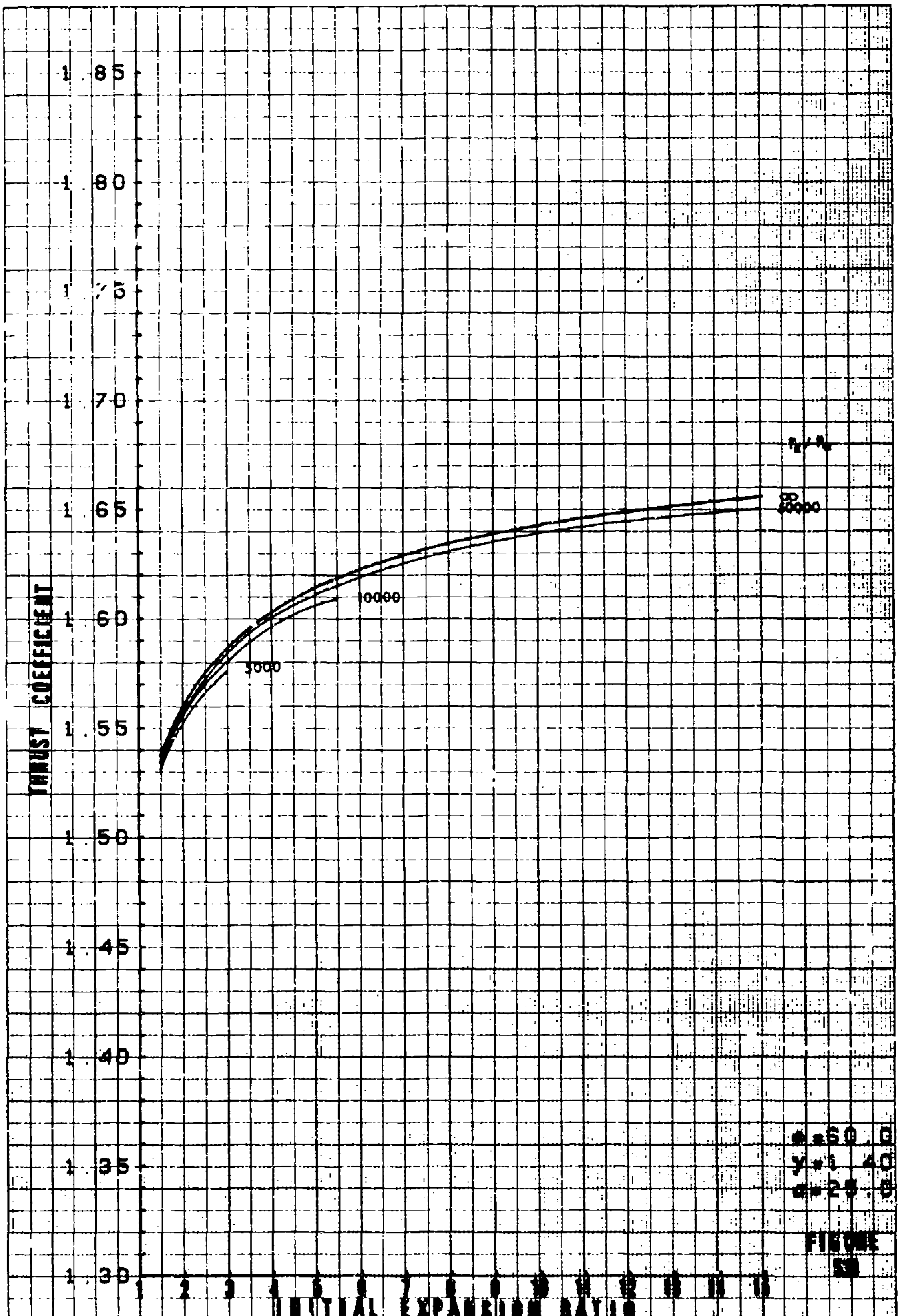

THRUST COEFFICIENT
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
2000
1000
500
∞
φ = 55.0
γ = 1.40
α = 25.0
FIGURE
535

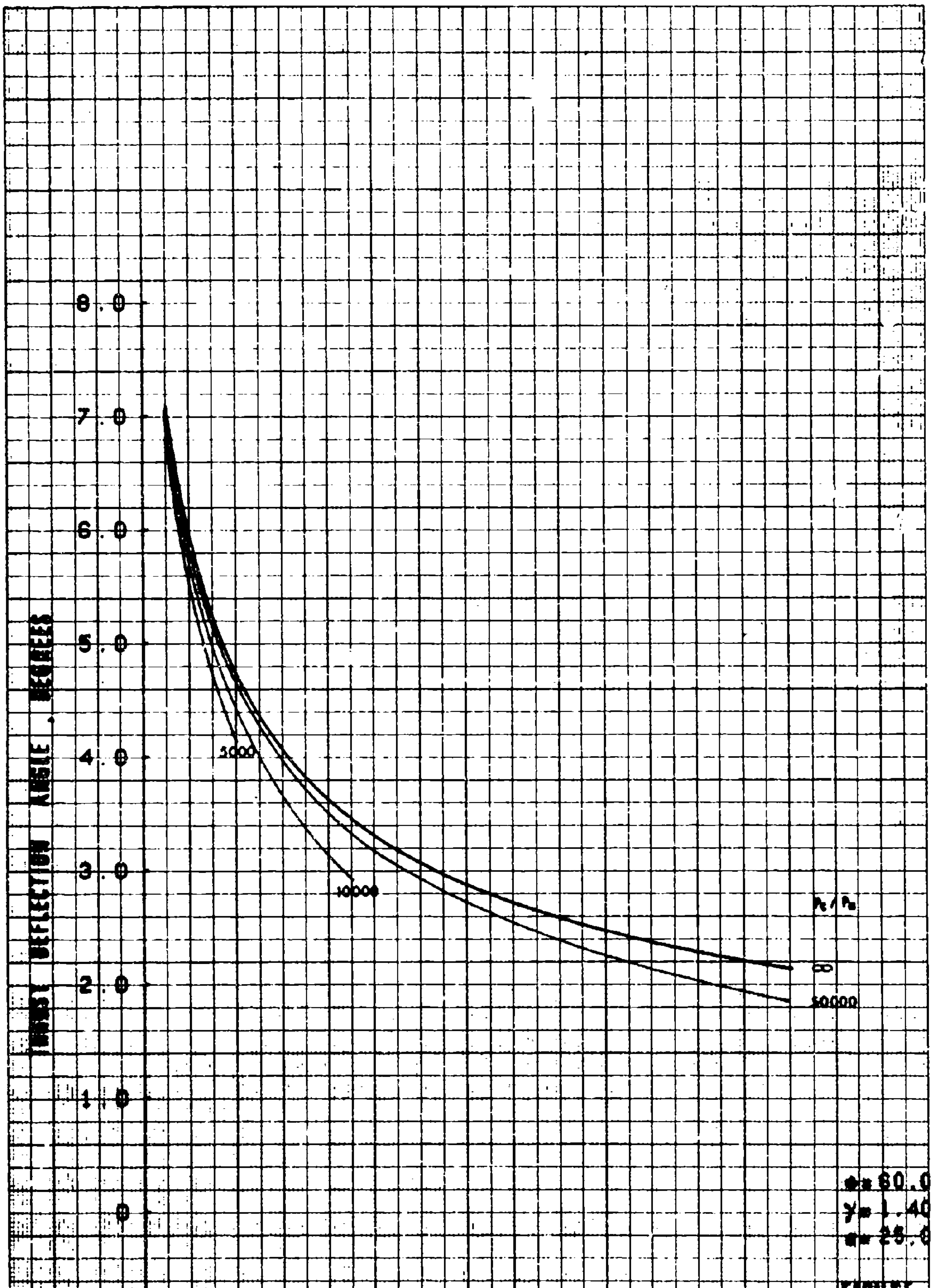


7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
1.0
THRUST DEFLECTION ANGLE, DEGREES
500
1000
2000
P_c/P_a
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
ϕ = 55.0
γ = 1.40
ϵ = 25.0
FIGURE

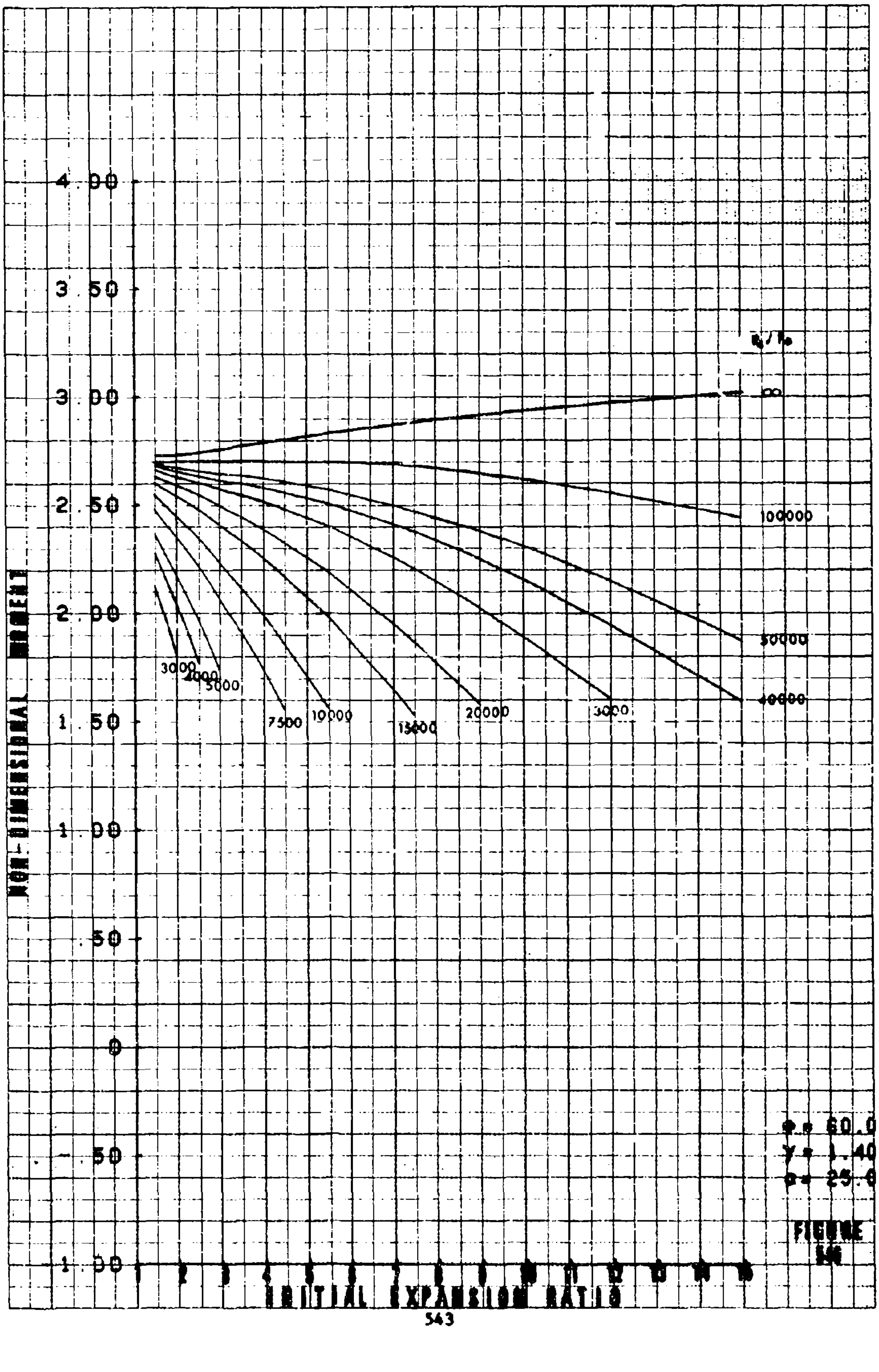


2.00
1.75
1.50
1.25
1.00
.75
.50
.25
0
-.25
-.50
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
∞
20000
10000
7500
5000
4000
3000
2000
1500
1000
500
γ= 1.40
FIGURE


1.85
1.80
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
THRUST COEFFICIENT
10000
5000
FIGURE



8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
1.0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
5000
10000
P_c / P_a
∞
50000
INITIAL EXPANSION RATIO
FIGURE



NON-DIMENSIONAL MOMENT
INITIAL EXPANSION RATIO
4.00
3.50
3.00
2.50
2.00
1.50
1.00
.50
0
-.50
-1.00
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
∞
100000
50000
40000
3000
4000
5000
7500
10000
15000
20000
30000
FIGURE